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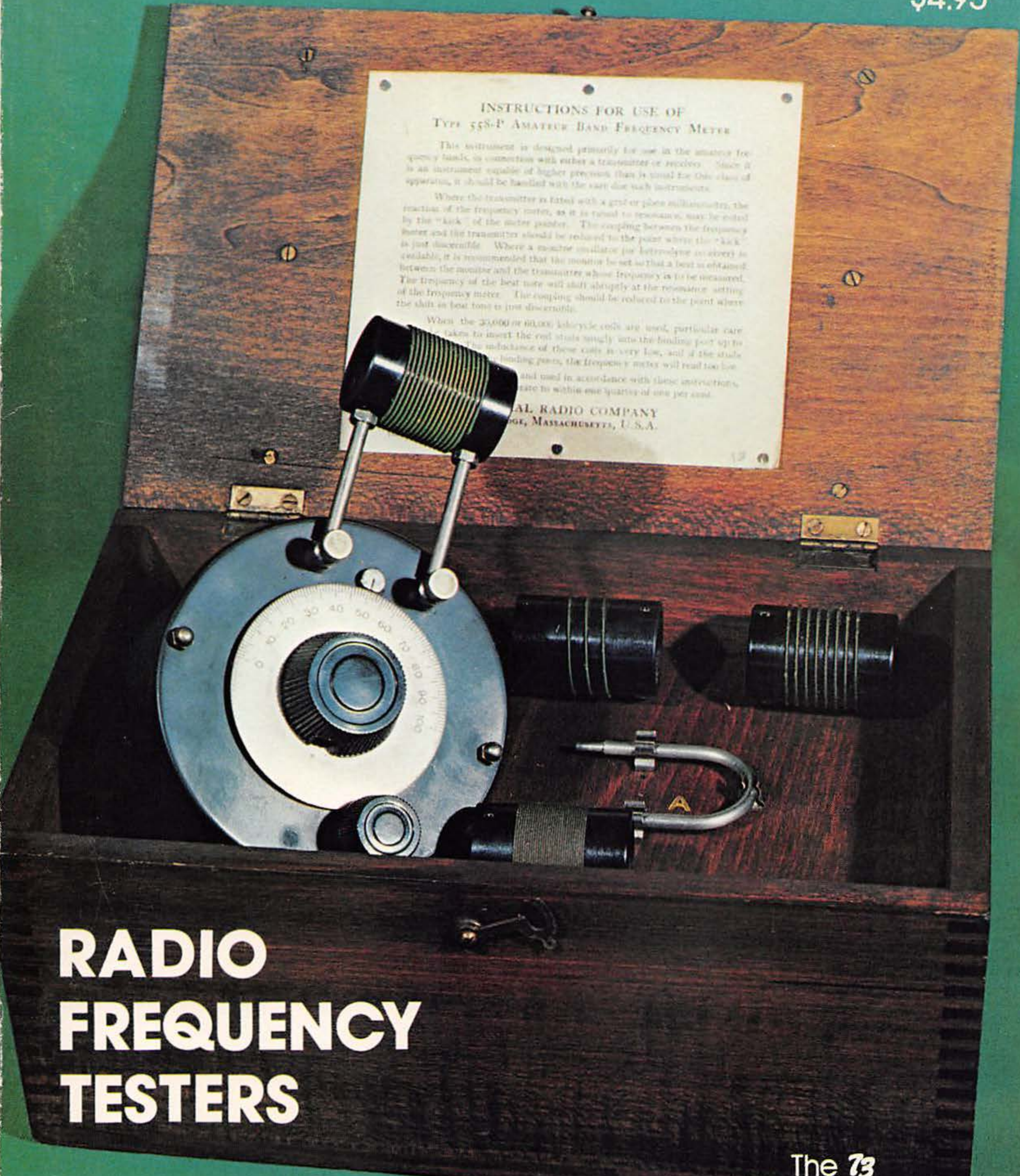


RADIO FREQUENCY TESTERS

77 Pieces of Test Equipment You Can Build!

The 73 Test Equipment Library
volume III

Table of Contents

The 73 Test Equipment Library

Volume III: Radio Frequency Testers

Chapter I

What is Your SWR, OM?

SWR POWER METER FOR 80 THRU 10m BANDS

James Lee W6VAT

WITH the declining sunspots, usage of the lower frequency bands is definitely increasing. The resulting increased QRM is helpful to no one and only efficient equipment and operating procedures will result in a maximum number of QSO's. The SWR/PWR meter described here won't make you a better operator, but it can help you be sure that you are delivering the most rf to your antenna from your rig. Fig. 1 shows a front view of the meter.

The basic circuit is a directional coupler switched to sample either forward or reverse voltage and a voltmeter to read this voltage.

This type of coupler has an output proportional to length, power, and frequency. The longer it is, the more output it gives. Since it puts a small impedance "bump" in the line, the length of the coupler should be limited to not over 1/20 wavelength at the highest frequency, or it may begin to contribute noticeably to the SWR itself. For a given power, if the frequency of the rf flowing through the coupler is reduced, the maximum coupler output is reduced. This means that you can get full scale readings on 10 M with a lot less power than on 80 M. The meter described here gives half scale deflection on 40 M, at maximum sensitivity, with about 350 watts of forward power. If your rig is a KW this meter will fill the requirements for SWR/PWR measurements nicely. It can be left in the line at all times to monitor SWR or Power delivered to the antenna or other load. If desired, a Barker and Williamson type 551A coaxial switch can be used to insert the meter in the line for test purposes and then switch it out during operating periods.

Construction

The unit is built in a gray hammertone LMB type 141 box. The dimensions of this box are 3" x 4" x 6". Fig. 2 shows the parts placement and should answer any questions concerning layout.

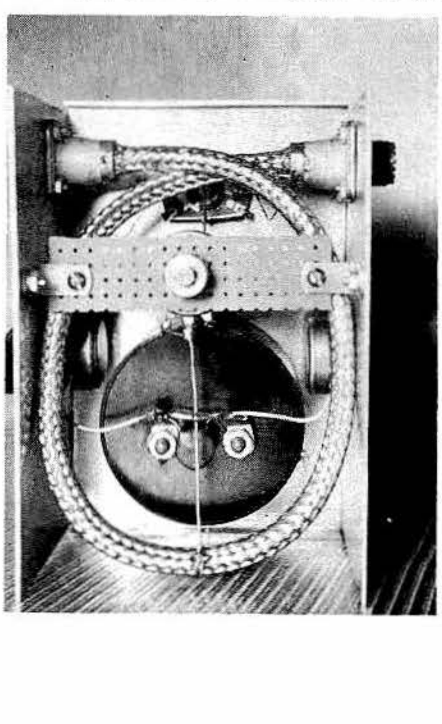
The coax directional coupler is made from a 14" length of RG-8/U. The outer covering is slit lengthwise with a knife and peeled off. Take care here not to cut into the woven braid. The woven braid is then bunched toward the center to loosen it. Next, a length of #22 enameled wire is passed through the braid at about 2¼" from one end and run under the braid next to the inner insulation. It is brought out at the other end, again 2¼" from the end of the shield braid. When this is done, smooth the braid back to its original position carefully to avoid scratching the enamel on the #22 wire. The #22 enameled wire should lay as straight as possible under the braid. It should have no slack nor should it twist around the inner insulation to any great degree. The ends of the shield braid are trimmed back far enough to be soldered to Amphenol 83-1H hoods. The inner insulation is trimmed off so as to expose about 3/16" of the inner conductor. The inner conductors are then soldered to Amphenol 83-1R female type chassis mount coax connectors. The coupler may now be set aside and the rest of the meter constructed.

Potentiometer R_1 is mounted on 1/16" x 1" x 4" piece of bakelite and positioned approximately in the center of the box to minimize capacity to ground. The metal rear cover is removed from the pot for the same reason. The pot ground lead is to the center of the coax and is wire in last. The diode D_1 should be protected from damage by heat when soldering it in the circuit. Long nose pliers gripping the leads near the body of the diode are satisfactory. The directional coupler is the last item soldered in place. As can be seen in the photos—the coax connectors are mounted from the inside of the box. When the #22 enameled leads are soldered to S_1 they should be the same length, and again, take care not to scratch the enamel or a short circuit may occur and you'll have to do it all over again.

Calibration

There are any number of ways to calibrate the SWR/PWR meter, but the way most hams will use is their own rig and a suitable dummy load. Though very limited in power, a 2 watt 50 ohm resistor such as made by Ohmite, IRC and others, mounted inside an Amphenol 83-1SP male coax plug makes a very good dummy load. Although not completely non-inductive, this dummy load is far superior to such real unknowns as light bulbs, electric iron heating elements, etc. This particular load is 50 ohms shunted by 6 mmfd over the range of 3-30 mc. It is a good dummy load—though a low power one.

With the back cover off, attach the dummy load to J_2, the load jack. Set R_1, the Sensitivity Control, to maximum and S_1 to FORWARD. Next apply power by hooking your rig (or



other rf source) to J_1, the transmitter jack. Make sure that the rf applied is 28-30 mc, or, the highest frequency you operate in the 3-30 mc region. This meter is sensitive to frequency. Stray capacities and other unbalances will have their greatest effect at the highest frequencies. In any event, calibrate the unit on the highest frequency your rig will tune in the 3-30 mc region. With power applied, set R_2 so the meter reading is at least half scale and switch S_1 to REVERSE. This will result in a lower meter reading. R_1 should then be adjusted for a minimum reading on the meter. Using the suggested load, you will not get a complete null, but the null should not be much more than 50 ua for half scale deflection in the FORWARD position on S_1. Don't put too much power into the dummy load since excessive dissipation can ruin it and change its characteristics greatly. If you have a higher power dummy load whose characteristics you know accurately, by all means use it, but remember a light bulb is not a good load. Once nulled, lock the nut on R_1 taking care not to disturb the setting. Replace the back cover and using the dummy load, recheck the null to make certain that it has not shifted.

Using The Meter

To make SWR measurements you need only insert it in the line and set S_1 to FORWARD and S_2 to SWR. Adjust the sensitivity control for at least a half scale reading. Then switch S_1 to REVERSE and read the value. SWR is then calculated by the following:

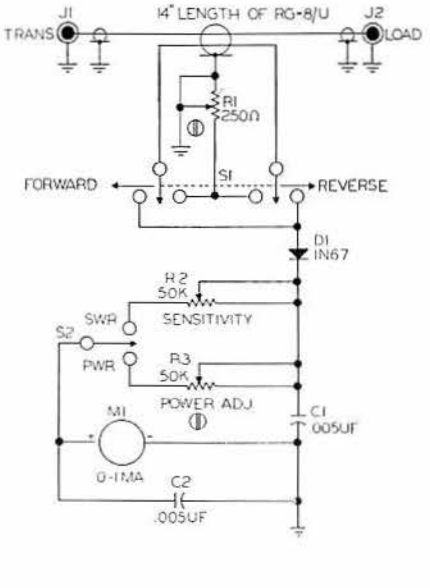
$$SWR = \frac{I_{fwd} + I_{rev}}{I_{fwd} - I_{rev}}$$

For example:

let $I_{fwd} = 500$ ua and $I_{rev} = 50$ ua, then

$$SWR = \frac{500 + 50}{500 - 50} = \frac{550}{450} = 1.22{:}1$$

The meter is useful for tune-up purposes where exact SWR is not needed. Just keep the FORWARD reading at a constant value and tune for minimum REVERSE readings. The exact SWR can be calculated when you have found the lowest REVERSE position.



The POWER position may appear to be essentially the same as the SWR position and it is. When measuring power into a load of known fixed value you only need to know the voltage across (or the current through) the load. The POWER position on S_2 is used with S_1 set to FORWARD. R_3 is merely set to a scale reading that is convenient for all bands if only a relative reading is used. If a good 50 ohm high power dummy load is available, you may make accurate calibrations by using a VTVM plus high frequency detector probe and measuring the actual voltage across the load. Just put a T-connector on the load jack J_2. Put the dummy load on one arm of the "T" and read the voltage at the other arm. 200 volts across a pure resistive load of 50 ohms is equal to 800 watts of power. If your rig delivers a key down 800 watts to a load then you could set R_3 at 0.8 ma on the scale, etc. The scale will not be precisely linear, particularly at low powers, but if enough resistance is used at R_3 the effects should be minimum. Since the coupler voltage is frequency sensitive one setting of R_3 will not hold for all bands. If desired, R_3 could be replaced with a switch and a number of selected resistors (one for each band). This would keep the scale factor constant between bands. This could be done for R_2 as well, but complicates an otherwise simple device

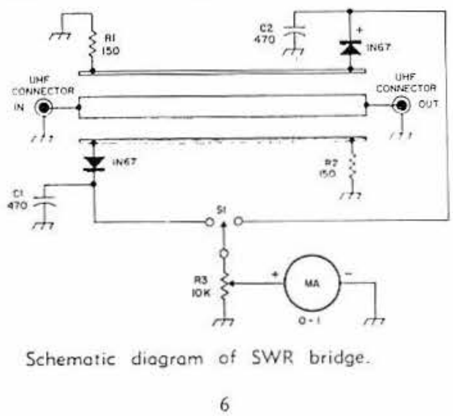
Operation

Once calibrated, the meter is very simple to use. Just hook it in the line at some convenient point and apply power. With S_1 set to FORWARD and S_2 set to SWR, adjust R_2 for at least a half scale reading. Switch S_1 to REVERSE and you will then be able to continuously monitor your reverse power. For power measurements, set S_1 to FORWARD and S_2 to PWR. Apply power and the meter will be monitoring your forward power continuously. R_3 is a screw driver adjusted pot. It can be set, and locked at a point which allows operation on all the bands you operate. The scale reading on each band will be different, but once set, these readings can be jotted down in your log book and any change quickly noted. This meter is also an excellent device for the antenna "tinkerer," or if you have coax coupling between stages in your rig it can be used to provide proper power transfer. Best of all, it is not expensive nor difficult to construct. Try one and you won't be without one again.

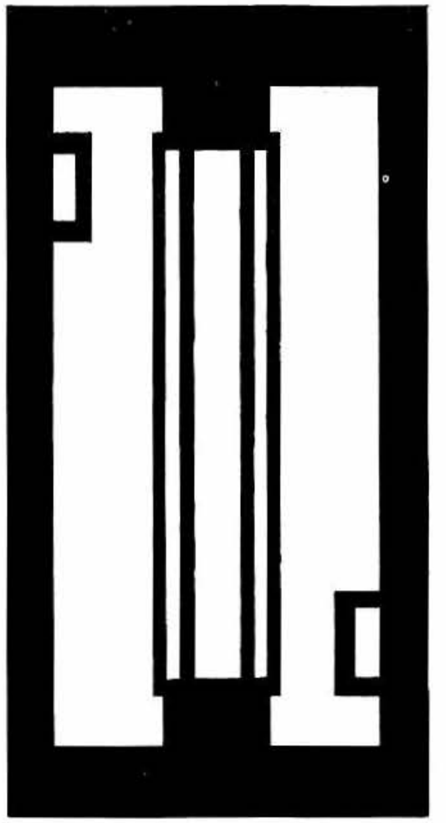
AN ETCHED CIRCUIT SWR BRIDGE

Ed Lawrence WA5SWD

Several of these boards have been etched and units assembled, and all have been satis-



Schematic diagram of SWR bridge.



factory. I have used mine, with a 200 microamp meter, from a kw on the low bands up to a "Twoer," with no problems with sensitivity.

Since Bud Miniboxes are commonly available, I scaled this board to fit into the Bud

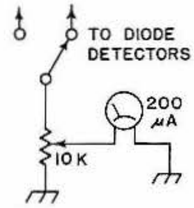
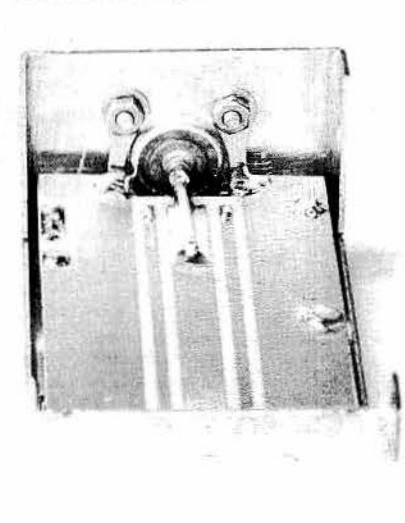


Fig. 1. Metering circuit for the etched circuit SWR bridge.



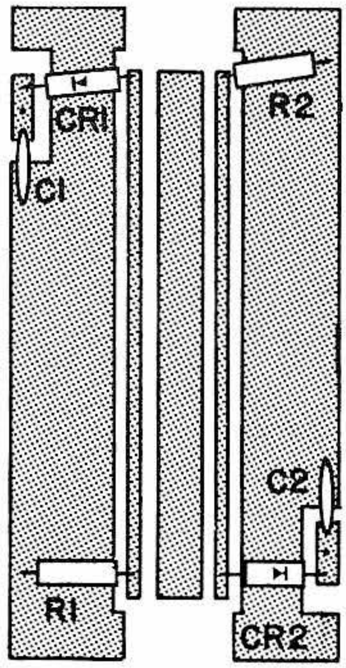


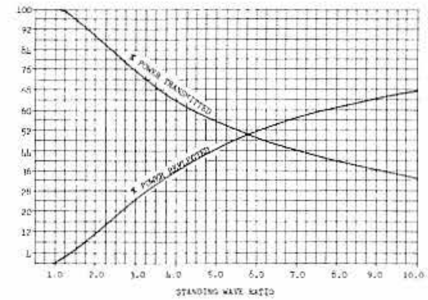
Fig. 2. Layout for the printed circuit board.

Minibox CU 2102A or CU 3002A. If you want to include the metering in the same package, the CU 2103A or CU 3003A should be used to give more room.

If you use the CU 2102A, center the coax connectors on the ends. If the CU 2103A, mount the connectors .8 inches from the open end. I used solder lugs bent at right angles to mount the P. C. Board to the chassis. The photograph shows the mounting much better than 10,000 words.

The meter sensitivity control circuit shown has a wider control range than the one shown in the *ARRL Handbook*, since the pot shunts the meter at low settings. This action could be accentuated by putting a fixed resistance in series with the meter movement, at the expense of sensitivity.

Although the virtues of operating transmission lines with low standing wave ratios (SWR) have been discussed many times in the past, evidently the economics of maintaining low SWR's are not readily apparent, particularly if the frequency of operation is low and the transmission line short. This has been reflected in various pseudo-technical QSO's where many have been led to the utter disregard for standing wave ratios. Most members of the amateur fraternity exist on limited budgets at best and when a significant portion of that precious transmitted power is eaten up by transmission line losses and misinterpreted standing wave ratios for naught, something should be done.



SWR vs % Power Transmitted and Power Reflected

Figure 1

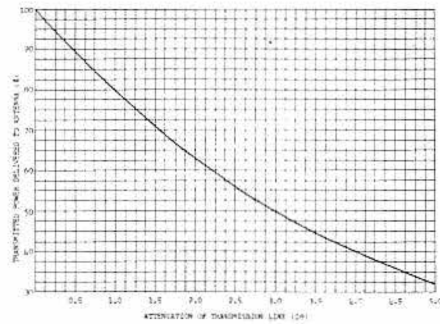


Figure 3

Attenuation vs Power transmitted.

A look at the graph in Fig. 1 will show you the percentage of power reflected for various standing wave ratios. For instance, if you are presently tolerating an SWR of about 5.8:1 (not uncommon in many ham shacks), 50% of the power which reaches the antenna is actually reflected back down the transmission line, heating up the final tank and causing TVI. Nor is only the transmitted signal effected, a high SWR will similarly degrade the received signal. This is particularly important in the reception of the extremely low level signals often encountered in DX and VHF operating. Stereophonic buffs should take heed too. A recent report by the IEEE (Institute of Electronic and Electrical Engineers) Professional Group on Broadcasting noted that a high SWR on receiver antenna inputs causes a reduction of stereo quality.

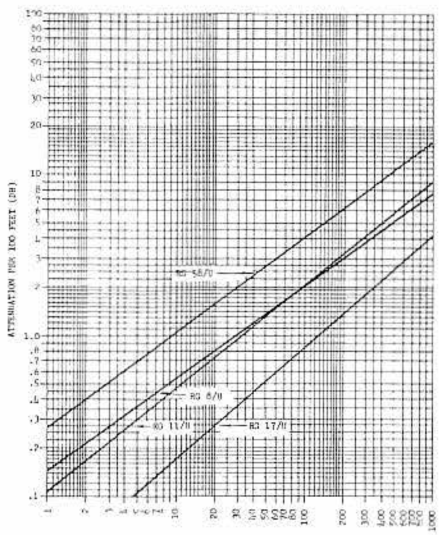


Figure 2

Attenuation vs frequency.

Many of the amateur stations on the air today make use of RG8A/U coaxial cable. Its excellence is proven out by its extensive use by the military, but a look at the loss graph (Fig. 2) for this cable indicates that it is not completely lossless! Even at 4 mc it has approximately 0.3 db loss per 100 feet, and on six meters there is a loss of 1.4 db for the same length. A look at Fig. 3 indicates that on 75 meters only 94% of the transmitted power is delivered to the antenna if 100 feet of RG8A/U is in use. At 50 mc the loss has sky rocketed to 26% for the same length of line. However, there is one big hooker for these conditions to exist: the SWR must be 1:1. For any other value of SWR there will be further line losses as shown in Fig. 4 because standing waves have the property of multiplying attenuation. This graph indicates that if a transmission line is operating at an SWR of 3.7:1, the line loss will be multiplied by a factor of two. For the previously mentioned situation on 50 mc, an additional 24% loss could be expected with an RG8A/U line operating at an SWR of 3.7:1.

It should be obvious by now that the use of an SWR bridge in the line at all times is very advantageous in the maintenance of a low SWR at the operating frequency. However, contrary to popular belief, the SWR bridge does not tell all. Since there is loss or attenuation in any length of transmission line, the reflected wave will be attenuated in the same matter as the transmitted or incident signal. Because the standing wave ratio is the ratio of the incident wave to the reflected wave, attenuation of the reflected wave will give erroneous SWR measurements when the SWR bridge is conveniently located at the transmitter. In this location the bridge will see the full power of the transmitter, but only a portion of the reflected signal. In some cases where the length of the transmission line is excessively long, the reflected wave will be attenuated to such a degree that the SWR will appear to be very close to 1:1, while in reality it will be a good deal higher. This fact is graphically represented in Fig. 5.

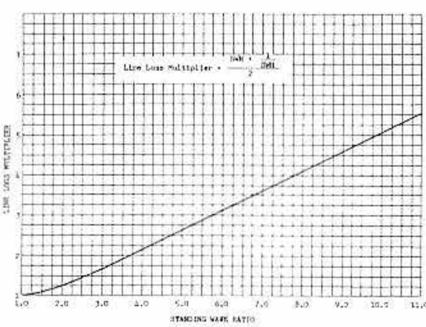
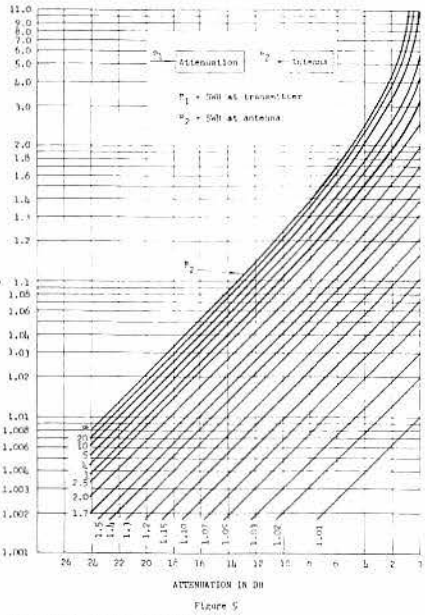


Figure 4

Line loss multiplier vs SWR.



SWR vs attenuation.

For example, 143 feet of RC8A/U at 50 mc would result in approximately 2 db attenuation. If an SWR bridge inserted in the line at the transmitter indicated an SWR of 2:1, this graph shows that an SWR of 3:1 exists at the antenna. A look at Figs. 3 and 4 will indicate that a 3.3 db loss (2 db times 1.65 multiplier) occurs, amounting to 47% loss of transmitted power in transmission line losses. Of the remaining 53% power arriving at the antenna, 24% will be reflected back down the line. A little simple arithmetic will show that of the total power transmitted, only 30% will be radiated! This simple mathematical fact should make the merits of low standing wave ratios immediately obvious if we wish to get the most out of our equipment. By keeping transmission lines short and by insuring that the SWR is as close to 1:1 as practicable, line losses will be minimized, maximum power will be delivered to the antenna and more successful and reliable radio communications will result.

CHECKING YOUR SWR INDICATOR

Carl Drumeller W5EHC

Many articles have been published on how to build and even some on how to calibrate a VSWR indicator. The calibration instructions usually tell you to terminate the indicator's output with a purely-resistive 52-ohm load and then to adjust the device so that a maximum forward and minimum reflected meter deflections are obtained. Sometimes they'll go further and tell you to reverse the device and recheck for opposite indications.

This is all very well. It assures you that the VSWR indicator will be telling you the truth when it says "All's well!" while looking into an utterly-flat transmission line. It doesn't tell you a thing about what the indicator will have to say when it gets tangled up with a line that has a wildly-mismatched termination.

As most transmission lines, in actual practice, are terminated in loads which are not only mismatched in the matter of resistance but also in the inclusion of a considerable magnitude of reactance, it would be well to explore the indications you'll get under realistic circumstances. After all, these are the situations under which you'd want to take corrective steps. Accurate indications of undesired conditions, therefore, are imperative if intelligent remedial actions are to be taken.

Fortunately, some quite enlightening tests are made easily. All you'll need are some lengths of coax transmission line (the same as you're using in your antenna feedline) equipped with male fittings at each end and a few female-to-female junctions. Select the frequency at which you want to make the test. Usually it's wise to make the test on the highest frequency band you plan to use. With this in mind, make up three one-eighth wavelength sections of transmission line and mount the male fittings on the ends of each section.

If your antenna presents an unmatched load to your transmission line, you may elect to skip over this paragraph and go directly to the next one. If it does not (Ah, you dreamer!), you'll need another piece of transmission line. It should be fairly long, perhaps a half wavelength. Put a male fitting at one end and attach a termination, which is deliberately made to be a sad mismatch, at the other end. Don't just mismatch it by using too high or too low a value of resistance. Throw in some reactance, too! You might use a resistor with an inductor in series. Or, you might try a capacitor in series with the resistor. Or, you could use either an inductor or a capacitor in parallel with a resistor. In fact, it would be best to experiment with all four!

Now that you have a transmission line available that you know is mismatched, you're ready to start the test. The first check (the "control", you might call it) is made with everything normal. That is, you'll have the transmitter feeding directly into the VSWR indicator's transfer box and the transmission line (either the one to your antenna or the substitute line to the mismatched load) attached to the output of the transfer box. Note the VSWR indicated. Also note your transmitter; insure that it's tuned to resonance and is adjusted to a power you can maintain throughout the first portion of the tests. Jot down these indications. Now, insert an eighth-wave section between the transfer box and the transmission line and without making *any* other changes or adjustments, note the VSWR. Repeat these steps, adding an additional eighth-wave section each time until you've used all three. Did you detect any change in VSWR? If there was even the slightest change, your VSWR indicator is not trustworthy!

Now for two more checks. Try varying the transmitter power output. Does this have any effect upon the indicated VSWR? If it does, your VSWR indicator is not trustworthy! Then try varying the transmitter output tuning, deliberately throwing the stage out of resonance. Does this have any effect upon the indicated VSWR? If it does, your VSWR indicator is not trustworthy!

Few VSWR indicators under the $150 class will pass these basic tests. If yours doesn't, don't be perturbed. You have an instrument that still has a useful field of application. You can use it as a comparative indicator. For instance, if you're adjusting the gamma match at an antenna, it'll serve quite well; in this application, you're holding all of the significant variables constant, with the exception of one (the gamma match), the effect of which you want to observe. Your tests will have shown you the parameters you'll have to hold constant for any other than simple comparisons. In all probability, you will have found that measurements taken with different (electrical) lengths of transmission line are invalid. Also, it's probable that, owing to the non-congruity of diode curves, measurements will have to be taken at precisely the same level of rf power if accurate comparisons are to be made.

If you'll keep its very real limitations in mind, you'll find that even an inexpensive VSWR indicator has excellent potentials for useful measurements. But don't ask it to perform at levels that even its expensive siblings can't attain!

HOME BREW BRIDGE CALIBRATION

Clifford Honess W4OAB

This table is useful for all homebrew SWR bridges and gives the % reflected power and the % full scale reading in the reflected mode, when the meter is set at full scale in the forward mode.

SWR	% Pwr. Refl.	Refl. Rdg. in % of Full Scale
1.1	.2%	4.8%
1.2	.8	9.1
1.3	1.7	13.1
1.4	2.8	16.7
1.5	4.0	20.0
1.6	5.3	23.1
1.7	6.7	25.9
1.8	8.2	28.6
1.9	9.7	31.1
2.0	11.0	33.3
2.1	12.6	35.5
2.2	14.0	37.5
2.3	15.5	39.4
2.4	17.0	41.2
2.5	18.4	42.9
2.6	19.7	44.4
2.7	21.1	45.9
2.8	22.5	47.4
2.9	23.8	48.7
3.0	25.0	50.0
4.0	36.0	60.0
5.7	49.0	70.0
9.0	64.0	80.0
19.0	81.0	90.0

MINI SWR BRIDGE

John Schultz W2EEY

Most SWR meters today are of the coupled variety which can be left in a transmission line while a transmitter is operated at full power. However, for a number of prolonged

tune-up operations, involving antenna matching systems, for instance, such couplers have several disadvantages.

On 160 and 80 meters, especially, a reasonable amount of power is necessary to produce full deflection—up to 100 watts with some configurations. With a very low-powered transmitter, making adjustments at this power level certainly may damage the output tube or tank-circuit components with a high SWR. This will not be the case with higher-powered circuits but, in any case, a signal strong enough to cause needless QRM will be radiated.

Another disadvantage of the coupled SWR meter, if it is home constructed, is that it must be carefully calibrated since its response is very dependent upon the mechanical configuration of the coupling circuit. This is unlike the bridge-type SWR meter (described in this article) where a standard SWR curve may be used with a good degree of accuracy.

The above factors, plus the fact that I didn't need an SWR meter continuously in the transmission line, led me to construct the little resistance type SWR bridge shown in the photograph. It is just about as simple and inexpensive a unit as can possible be built.

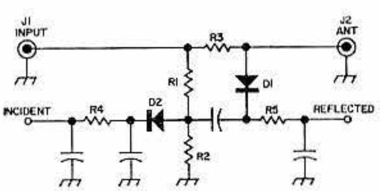


Fig. 1. SWR Bridge Circuit. See text for values of R_1, R_2 and R_3. R_4 and R_5 may be any matched value from 10 k to 47 k. D_1 and D_2 are IN34, IN54, or similar types. All capacitors are disc ceramic, .005 MF, 100V.

Construction

Two SO-239 coax chassis connectors are joined back to back by two 1¼ inch threaded hex spacers. The two four-lug terminal strips are mounted at the ends of one of the spacers. The wiring of diodes D_1 and D_2 as shown in **Fig. 1**, should be such that the incidental voltage-measuring point appears on the terminal strip mounted on the "input" SO-239 connector, in order to avoid confusion in measurement. Short leads, of course, should be used but hardly anything else is possible with only 1¼ inches between connectors.

Some attention must be paid to the components used if accurate readings are to be obtained. Resistor R_3 must closely match the impedance of the coaxial line used (52 or 75 ohms). For 52-ohm lines, a suitable resistor (within ½ to 1 ohm) can usually be found from a group of standard 10% tolerance, 47-ohm resistors; and for 75-ohm lines, from a group of 68-ohm resistors. Resistors R_1 and R_2 can have any value from about 30 to 100 ohms, but it is important that they are as closely matched as possible. One trick which may be used to affect very small resistance changes is to file "V" notches in

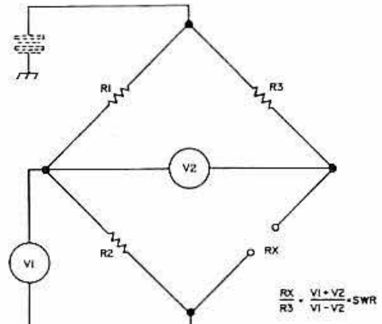


Fig. 2. Simplified diagram of SWR Bridge. V_1 represents incident voltage and V_2 the reflected voltage.

a composition resistor to raise its resistance. Two-watt units are suggested for these resistors because of their longer-term stability and endurance in case too much input power is applied.

Resistors R_4 and R_5 serve as linearizing resistors so that almost any meter with a basic movement of 1 mA or less can be used as an indicator. The lower dc voltage ranges on almost any VOM will work fine. These resistors as well as diodes D_1 and D_2 should be checked to see that they match reasonably well (the resistors within a few precent and the diodes within a few percent for their forward and reverse resistance readings).

Calibration

There are really no adjustments that can be made to the bridge, and calibration really consists of checking the balance. **Fig. 2** is the dc circuit of the bridge (a simple Wheatstone bridge with resistance arms). If the balance of the bridge is good, V_2 should be the same when points R_X are opened or shorted so long as V_1 is held constant. This can be checked on the actual bridge by applying an input at the highest frequency of interest (6 or 10 meters), shorting J_2, and checking that incident and reflecting voltages are the same. The same is done with J_2 open. If the voltages are not equal, the difference can be taken as an indication of how accurate the SWR readings will be. If the difference is too great, R_1 or R_2 will have to be changed for a better match or the mounting of the components changed to reduce stray couplings.

A further check is to connect a known 52 or 75 ohm resistor across J_2. The reflected voltage should, of course, read zero.

Operation

As noted in **Fig. 2** the actual SWR is a simple function of the incident and reflected voltage readings. **Fig. 3** presents this function in graphical form. The incident voltage is simply adjusted for some convenient value,

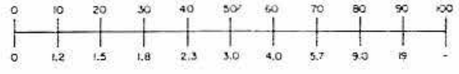


Fig. 3. SWR values for selected reflected voltage readings taken as % of incident voltage reading.

say 10 volts reading on the dc scale of a VOM (possible with most SSB transmitters by adjusting the carrier balance control with no audio input). The reflected voltage is then read as a percentage of the incident voltage and the SWR found from **Fig. 3.** The input power required to operate the bridge is essentially independent of frequency, being about 1-2 watts maximum.

It should be remembered that such a bridge can measure only the resistive portion of an impedance. When using it to adjust a circuit, if a SWR minimum null but not a zero reading for reflected voltage can be obtained, it indicates some reactive component must still be present.

VSWR SUPREME

E. L. Klein W4BRS

One of the most valuable tools used by the amateur is the Voltage Standing Wave Ratio Meter. It ranks with the grid-dipper and the plate current meter as an indispensable instrument around the ham shack. We know that the VSWR meter is very handy in indicating relative power output when tuning a transmitter, particularly when the plate dip is not too discernable. It is most useful, however, in proving that the last available watt has reached the antenna where it can do some good.

Why a good match?

Although a good copper connection is made all the way to the antenna, an efficient transfer of power may not be achieved because of a mismatch between the characteristic impedances of the various portions of the transmission system. The interesting thing is that the "match" is different for each frequency because the antenna is essentially a single frequency device.

We can appreciate the importance of a proper match between the transmitter and the antenna when we are told, for example, that a VSWR of 3 to 1 causes a power loss of nearly 3 dB for 200 feet of RG-8/U coaxial line at 30 MHz. The table below provides

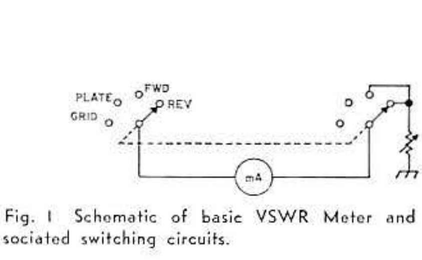


Fig. 1 Schematic of basic VSWR Meter and associated switching circuits.

Table I

VSWR	Power Loss (dB)	Transmitter Power Needed to Provide 1 kW at the Antenna
1.5:1	2.1	1600 watts
2:1	2.3	1700
3:1	2.8	1900
4:1	3.3	2000
5:1	3.7	2300
7:1	4.5	2800
10:1	5.3	3400

Additional power needed to compensate for a poor impedance match between transmitter and antenna. Figures are based upon 200 feet of RG-8/U cable at 30 MHz.

the real reason why we should be concerned with the impedance match. Notice how much the transmitter power would have to be increased to make up for a poor match between the transmitter and the antenna. Incidently, this match involves each and every part of the total transmission system including connectors, antenna relay, low-pass filter, balun, etc., as well as the transmission line itself and that particularly critical point at which it is connected to the antenna.

A new approach

Most VSWR meters today are an external accessory to the transmitter. But this practice is not good. Coaxial connectors are expensive and cause unwarranted mismatch and power loss. Meter faces usually end up behind the transmitter or in some other inaccessible location. When switching from forward to reverse, the little accessory box scoots across the table leaving scratches and a distraught operator.

The transmitter plate current meter is no longer a plug-in accessory. Why should the VSWR meter be? (Believe it or not, plate meters used to be plugged in with phone jacks.) Using the simple design described here, the home constructor as well as the commercial manufacturer can now build the VSWR meter into the transmitter in the smallest possible space and at only pennies of cost.

The circuit

Nothing is new about the circuit. It has been adequately described in the past in magazine articles and handbooks. However, for the convenience of the reader, the VSWR meter circuit is reproduced in **Fig. 1** for handy reference. Terminating resistors R1 and R2 should be 33 ohms for a 50-ohm transmission line when the physical configuration, as shown here, is used. One-half watt or smaller size resistors may be used. Diodes CR1 and CR2 are any matched pair of silicon diodes or germanium. The types which are enclosed in glass cases are the easiest to use because of their small size. The ohmmeter can be used to select and match the diodes of the ten-cent surplus variety found in advertisements in ham magazines such as *73*. Bypass capacitors C1 and C2 are 1500 pF Centralab type FT-1500.

Physical components

Parts used in this VSWR meter are illustrated in **Fig. 2**. The brass tubing is about 5 to 7 inches long and of 5/16 inch outside diameter. This size tubing fits snugly around the inner polyethelyne insulation from RG-8/U coaxial cable. About 10 inches of coax is stripped of its outer jacket and braid. The inner insulation is trimmed to extend 1/8 inch past each end of the brass tubing. Two large solder lugs are selected to fit over the 1/4 inch threaded shank of the bypass capacitors. These lugs should be of the long variety so they may be shaped and soldered to the brass tubing as shown in **Fig. 3**. Two 8-inch pieces of #22 enameled copper wire are also required.

Assembly

After soldering the lugs to the brass tubing about 5/8 inch in from each end, the bypass capacitors are assembled to the lugs. Place several fiber washers under the ring nuts prior to tightening them down on the threaded shank of the capacitors. This per-

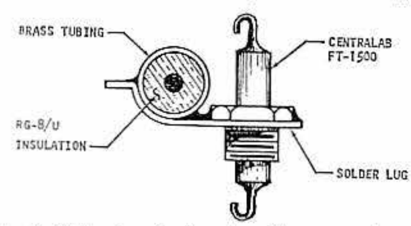


Fig. 3 Solder lug is shaped to fit one-quarter way around the brass tubing.

mits careful soldering of the capacitors to the lugs without danger of also soldering the nuts in place.

Two small grooves are now cut 180 degrees apart for the total length of the polyethelyne insulation. A small wood carving gouge or carefully manipulated razor blade can be used for this purpose. These grooves provide a space for the enameled copper wire which is held in place when assembling as shown in **Fig. 4**. Prior to this operation, the wire should be stretched and work-hardened by jerking it between two pairs of pliers. Be sure that the plane described by the two wires lies at right angles to the chassis on which the unit is mounted. This permits all resistors and diodes to have equal lead lengths.

When the inner assembly has been tugged and shoved into place within the brass tubing, the #22 wire ends are trimmed, stripped

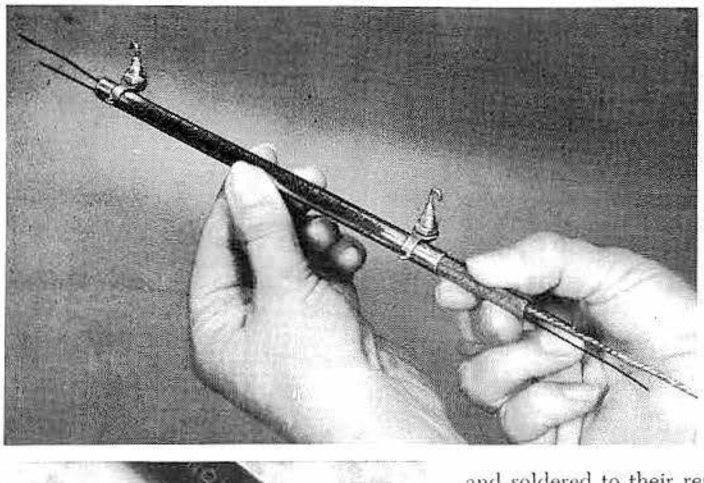


Fig. 4 Assembling the inner components into the brass tubing.

and soldered to their respective resistors and diodes. Much care should be exercised at this point to prevent melting the insulation or damaging the near zero-length component leads.

Application

A completed sensing unit for the VSWR meter is shown mounted on a typical chassis in **Fig. 5**. It will be noted that no conventional box or housing is used because the total outside of the unit is at ground rf and dc potential, save for the component connections at each end. By mounting the bypass capacitor in the chassis, the low-voltage rectified current fed to the meter switch is

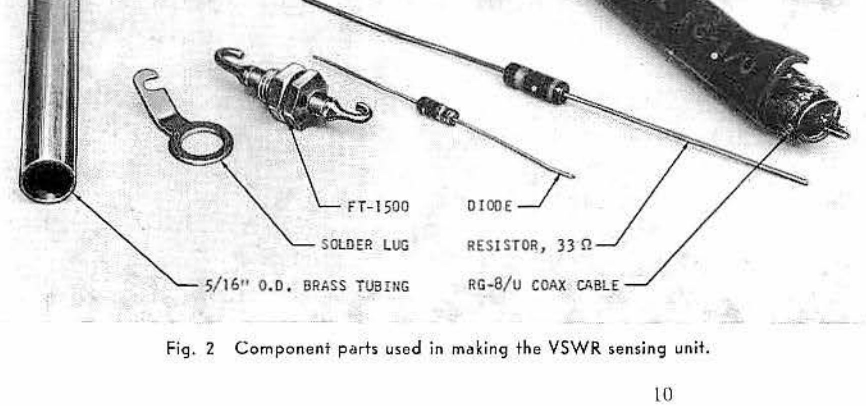


Fig. 2 Component parts used in making the VSWR sensing unit.

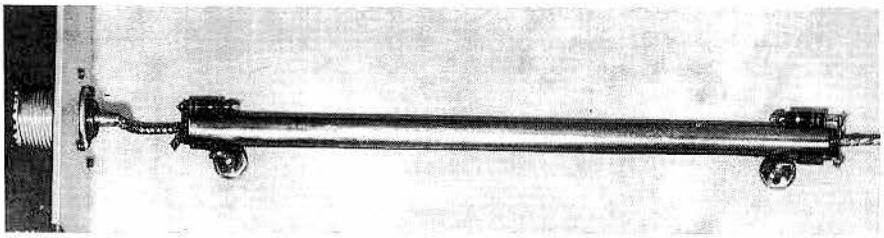


Fig. 5 Finished VSWR sensing unit mounted on a typical chassis.

isolated from high-power rf on the other side of the chassis. It can readily be seen that the finished sensing unit occupies no more space than would be used by a coaxial lead running from an antenna relay to the antenna connector on the chassis.

A further refinement is shown in **Fig. 6.** Complete isolation of the high-power rf is provided by the coaxial hood. Impedance discontinuity is also minimized by use of the hood, which was designed for this purpose and is readily available.

Length of sensor

The dimensions given for the length of the sensor element, including its outer tubing and inner conductor, are not critical. They are, however, directly related to the power of the transmitter with which the VSWR meter is used. For example, with a one kilowatt high-frequency CW transmitter and a 0-1 milliammeter as the indicating meter, the length of the sensor can be as short as 2-3 inches. A sensor which is constructed approximately 7 inches long, as illustrated in this article, will work fine with the same meter on a 25-200 watt high frequency transmitter. If meters with higher current ratings are used, a longer sensor is required, and, conversely, a more sensitive meter would provide adequate full-scale deflection with a shorter sensor element. Obviously, it is impracticable to vary the length of the sensor element in order to vary the sensitivity of the VSWR meter as a whole. It is for this reason that the adjusting resistor is provided in series with the meter. For VHF use, the sensor can be shorter.

All that has been said above can be depicted graphically. **Fig. 7** shows the generalized relationship between the sensor length and transmitter power with which it is used. The two curves represent different meter sensitivities. A 0-1 milliammeter offers a good compromise. With a 5-7 inch long sensor and the proper series resistor, all powers normally encountered in amateur work can be handled. However, if space requirements so dictate, a shorter sensor unit can be employed with some small sacrifice in accuracy.

Terminating resistor

Small variations in mechanical construction and lead dress will have an effect on the value of the terminating resistors, R_1 and R_2. Also, a carbon resistor does not display the same reactance at high frequencies as its measured resistance at dc. The value of the 33-ohm resistor was therefore determined empirically.

To verify the proper value of the terminating resistors, the test set-up shown in **Fig. 8** is used. A radio-frequency source of approximately 10 to 20 watts is required. A transmitter exciter stage operating on the 10-meter band is preferred for this purpose. Ten meters, or even fifteen meters, will provide better accuracy than one of the lower frequency bands. A dummy load is also required. This load must be capable of dissipating the power of the radio-frequency source used in making the test. Three or four 2-watt carbon resistors of the proper value in parallel to provide 52 ohms will suffice if the power is not left on continuously.

In making the test, the selector switch is first placed in the "forward" position. With power applied, immediately adjust the sensitivity control so that the meter reads full scale. Upon switching to the "reverse" position, the meter should read near zero and be at or below the 1:1 calibration point on the meter scale. Several resistors may be substituted until the proper value is found. The important thing to remember is that both of the resistors should be simultaneously substituted and that they must be as near identical as possible as measured on a reasonably good ohmmeter. Lead lengths should also be as short as possible and of identical length.

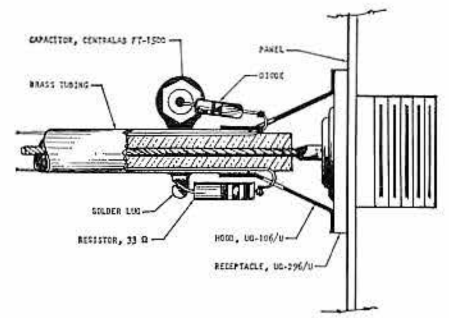


Fig. 6 Recommended chassis connection for output of VSWR meter sensing unit.

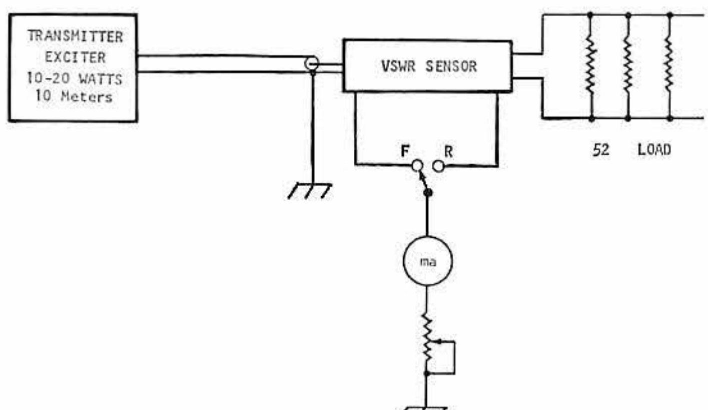


Fig. 8 Test set-up for verifying the proper value of the terminating resistors which are a part of the sensor unit. The value of the dummy load should match the characteristic impedance of the sensor unit and have a total wattage rating nearly equal to the source power.

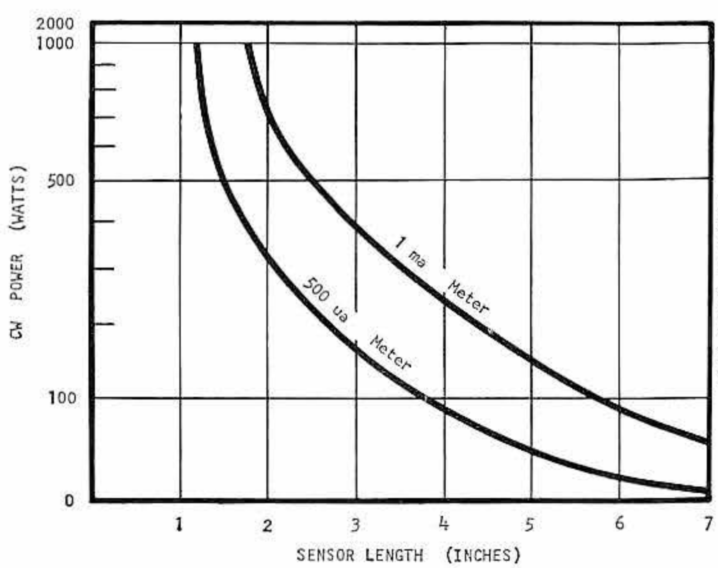


Fig. 7 The approximate relationship between sensor length and transmitter power is shown for two commonly used meter movements. Other meter values may be used as discussed in the text.

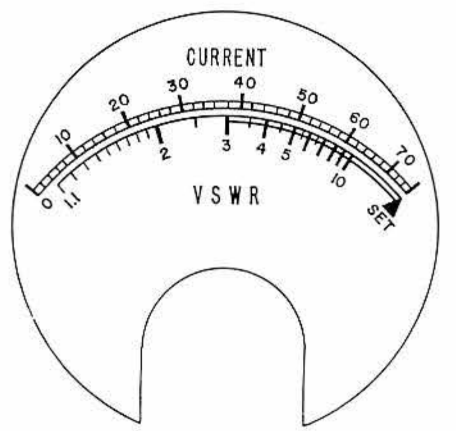


Fig. 9 Full-size photomaster of the VSWR meter dial. A multi-purpose meter was used in the author's transmitter so that the grid and plate currents could also be read on the upper scale.

The dial scale

Using the standard formula for calculating VSWR, it is possible to calibrate the meter face as follows:

$$\text{VSWR} = \frac{\text{forward} + \text{reverse}}{\text{forward} - \text{reverse}}$$

Fig. 9 is a full-scale illustration of a meter face used with the *VSWR Supreme*. This scale fits the Triplett Model 327, as well as a number of other meters of the same size category. A word of caution—don't assume that the scale calibration, or linearity will be the same for all makes of meters. The individual meter movement selected should be checked by using the above formula and marking off radials representing 4-5 different VSWR values. With the scale from your meter at the center of an oversized radial(s) drawing, it is possible to verify the angular placement of each VSWR calibration point.

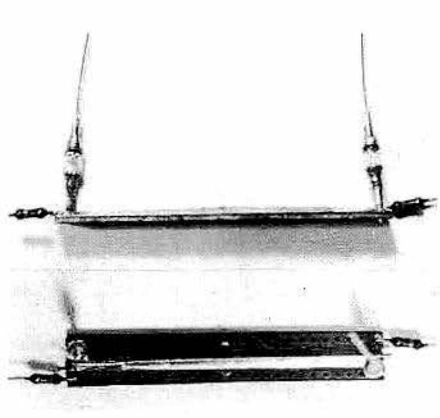
The *VSWR Supreme* is truly a novel approach to an old standby. Using the construction methods outlined in this article, it is possible to fabricate the sensor unit so that it occupies the smallest possible space. This sensor can now be built into a transmitter and take up no more room than the coaxial lead which it replaces.

A SIMPLE VHF SWR METER

John Schultz W2EEY/K3EZ

I recently wanted to do some work on a 2 meter antenna and since no other instrument was handy, started to use an SWR meter manufactured for use on the high frequency bands. After some erratic results, it was decided to check the SWR meter accuracy on 2 meters with some carbon resistors to simulate different SWR's. The results readily confirmed that the SWR meter was useless at VHF unless one didn't care whether a SWR was really 1:2 or 1:5. Rather than purchase another SWR meter, it was decided to construct one that would render reasonable results, within 10% accuracy or so, on the VHF bands, particularly 144 and 220 MHz.

There is nothing basically new in the circuitry of the SWR meter to be described. What is different about it is that it utilizes a particularly simple and inexpensive method of construction that yields reasonable results. It can be constructed as a completely self-contained SWR meter or only the pickup element can be constructed and used with an external meter. The circuitry as shown here for the meter utilizes two meter movements so one can read forward and reflected power simultaneously and avoid the annoyance of having a forward-reflected switch arrangement for a single meter.



The heart of the SWR meter is a carefully constructed pickup element. Details of construction are discussed in the text but the photo shows how closely the diodes and terminating resistors must be soldered to the pickup element.

Pickup Element

The "heart" of any SWR meter of the reflectometer type is the pickup element. Many elaborate forms for such elements have been devised which involve complicated mechanical construction. Such complicated construction does become necessary if very accurate results are desired and if the meter is to maintain linearity over a very wide frequency range. However, over a smaller frequency range and with some minor sacrifice in accuracy, the construction of a pickup element can be greatly simplified. Basically, the pickup element should not cause any discontinuity in the transmission line section in which it is inserted but yet be long enough so enough voltage can be picked up in both the forward and reflected directions to make the meter usable with even low power transmitters.

The pickup element I devised is shown in the photo. It is a 2-7/8" long piece of alternate grid pre-punched perf-board stock. The board is about 7/16" wide and within this width contained 4 separate copper strips spaced about 1/16" or less apart. The center two strips are soldered together to act as the inner conductor continuation of a coaxial line section. To solder the two inner strips together tack solder a bare piece of hookup wire between the two strips and then cover the entire two strips with solder.

Without the use of pickup wire, it will be nearly impossible to develop a smooth solder flow between the strip. Each outer strip acts as a pickup element for the SWR meter circuit shown in Fig. 1. The terminating resistor and diode are soldered to each end of the outer strip as shown in the photo and with minimum excess lead length to the strip. The use of a heat sink on the diode is necessary to prevent damage during soldering.

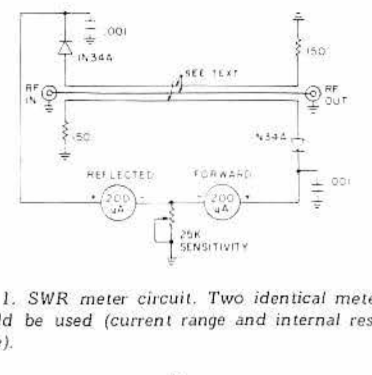


Fig. 1. SWR meter circuit. Two identical meters should be used (current range and internal resistance).

Mounting The Pickup Element

The pickup element made from the board stock is mounted between two approximately spaced SO-239 chassis connectors. The center strip of the board is soldered at each end to the center post of the SO-239 connector. The terminating resistor at each end is grounded as directly as possible to a ground lug held in place by one screw of the SO-239 mounting hardware. These details are shown in Fig. 2. It is important that the terminating resistor be grounded in this manner with minimum lead length. The enclosure in which the pickup element is contained should just be wide enough to accommodate the SO 239 connectors so that when the enclosure is secured together, the pickup element is boxed in by a metal surface on each side except directly above it. Many chassis or enclosure types are suitable for this purpose and the overall size of the enclosure will depend, of course, on the meter used and sensitivity control placement. These details are not covered here because they can be made as desired. They will not affect the basic accuracy of the meter as long as the pickup element is properly mounted and enclosed. The bypassing of the pickup rectifier diodes must also be done with as short leads as possible on the bypass capacitor. As shown in Fig. 2, a two lug terminal strip (one lug grounded)

mounted on the side wall of the enclosure immediately at the cathode end of the diode will perform this task very well. The length of the IN34A diodes is such that the bypass capacitor cannot be connected to the same ground lug used for the terminating resistor. The leads on the capacitor would be too long and it will be ineffective.

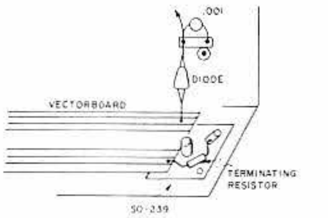


Fig. 2. Center strip of vector board is soldered to center post of SO-239. Other components are mounted at each end of board as shown (only one end shown here).

Operation and Results

The dual meter circuit of Fig. 1 reads forward and reflected power simultaneously. The sensitivity potentiometer is set to read full scale on the forward meter and the SWR read directly from the reflected meter. The latter meter can be calibrated for various SWR's by the use of small carbon resistors (100Ω to simulate a 1:2 SWR in a 50Ω line, etc.). Usually, it is only necessary to calibrate the reflected meter for SWR's of 1.5, 2 and 3 at the frequency of interest. Calibrated in this manner, the accuracy of measurement will be roughly 10% and is certainly good enough for most general antenna work. A particularly nice meter display can be made if one can find a two meter movement in one enclosure. I purchased a surplus stereo VU meter which had dual 200 μA movements and used it in the SWR meter.

The sensitivity of the SWR meter is such that transceivers of the 1-2 watt output class can easily be used with it on the VHF bands. The basic meter, of course, can also be used on the lower frequency bands as well and it will retain good accuracy. The only problem on the lower frequency bands is that the pickup strips are so short that more transmitter power has to be used to activate the meter than is usually convenient to use during antenna experiments. No exact tests were made but probably 70–100 watts would be needed to use the meter on as low a band as 80 meters. The meter was used and checked, however, on 40 meters. The accuracy of the meter remained very good and full scale deflection of the forward level meter required a power level of 60 watts. Being an in-line type meter, it can be left permanently in line when used on any band with a minimum of loss.

DIRECTIONAL COUPLER AND VSWR BRIDGE FOR VHF AND UHF

Bob Kolb WA6SXC

The aerospace industry has fostered the development of many new components and materials. Hams, being the kind of people they are, are quick to see practical applications for these materials that never occur to design engineers. I have often heard the criticism that it is impractical to publish articles or design ham gear with these new or expensive materials, because most OM's don't have access to them. Yet I've often been dismayed when I learn of an application for a piece of surplus equipment after it is no longer available. For this reason I feel that we should publish any application that is practical regardless of how immediately it can be used. Sooner or later, the material will show up on the surplus market and then we'll know what use can be made of it.

Reliable test equipment for the VHF-UHF bands is difficult to come by on a low budget. The literature is full of "relative" measuring devices but few pieces of homebrew gear are engineered for repeatable performance. Several directional couplers have been built according to the description in this article and each has measured to within ±.5 dB of the designed value. This is due in part to the mechanical rigidity and close tolerance of RG-141 "coaxitube." No special tools are required outside of a cheap pair of vernier calipers. The tools used to make the original coupler were an Xacto knife, file, soldering gun, vernier calipers and a vise. Don't let the calipers scare you. If you're not after a closely calibrated device they may be omitted.

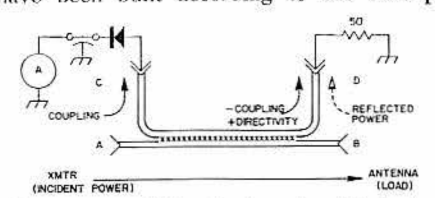


Fig. 1. A typical directional coupler. This device is the heart of a VSWR bridge, and can also be used for many other applications.

The design goal was a directional coupler with about 30 dB directivity in the passband with a low insertion loss. Each milliwatt measured at the coupling arm equals one watt through the main line. Such a device is the heart of a good quality VSWR Bridge. The measured values were 30.3 dB coupling and 38 dB directivity at 432 MHz. Data presented in the graph was taken using HP608C and 614A signal generators and a General Microwave R. F. Power Meter. The measured insertion loss was 0.2 dB.

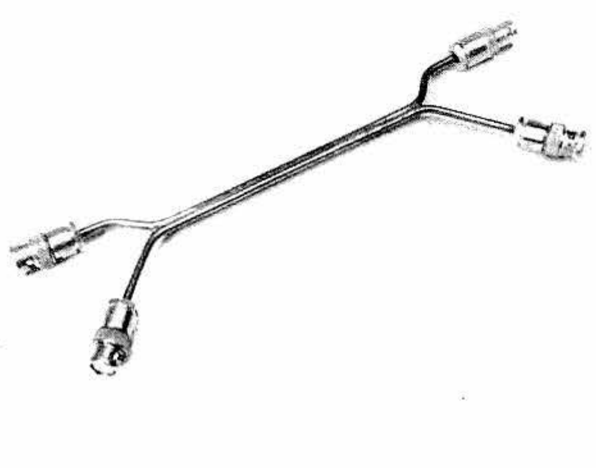
Resolution of the smallest possible VSWR is limited by directivity. Few of the handbook VSWR bridges or the low cost type attractive to the CB trade achieve as much as 20 dB directivity. Thus the minimum discernable VSWR is approximately 1.7:1. With 38 dB directivity, 1.02:1 VSWR's can be accurately measured.

Directivity may be defined as the isolation of arm D from arm A, over and above the coupling as shown in the **Fig. 1.** Coupling is achieved by removing part of the jacket between adjacent coax conductors. If the input is at arm A, incident power can be sampled 30 dB down at arm C but appears −68 dB at arm D. Reflected power entering arm B is sampled −30 dB at arm D while at arm C it is −68 dB. It stands to reason if the directivity is low, one cannot tell with certainty if he is measuring incident or reflected power. Port D may be used as the dc return for a detector at port C and vice versa.

This device will have its fundamental passband where the length exposed between the two lines is $\lambda/4\sqrt{\epsilon_r}$. It will also have a passboard at $(2n - 1)\ \lambda/4\sqrt{\epsilon_r}$ or at three, five, seven, etc., times the frequency for which it is a quarter wave. Hence a coupler designed at 432 MHz is usable at 1296 MHz.

This coupler has also been used to measure relative power and modulation at 2 meters where its coupling factor for incident power is approximately −40 dB but the directivity is poor, hence arm D must be terminated in 50 ohms. It's a real aid for tune up and will give a good indication of increased power with AM modulation right in the r.f. line. RG141 will handle 500 watts of rf up to 2000 MHz.

This UHF directional coupler is very simple to make, yet offers excellent performance on the 70 and 23 cm bands.



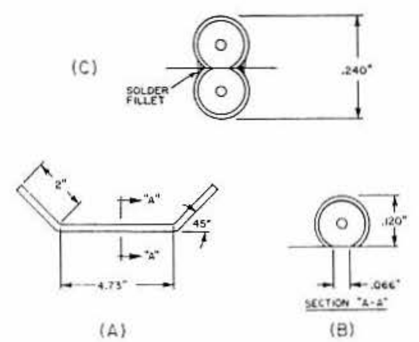


Fig. 2. Details of the construction of the UHF directional coupler.

The formula for determining coupling length is

$$\frac{c}{4 f_o \sqrt{\epsilon_r}} = \frac{\lambda c}{4\sqrt{\epsilon_r}} \text{ or } \frac{300 \times 10^8 \text{ cm}}{4 \times f_o \times \sqrt{2.1} \times 2.54 \ \text{cm}/_{\text{in}}}$$

$$= \frac{\lambda \text{ c inches}}{4\sqrt{\epsilon_r}}$$

$\sqrt{\epsilon_r}$ for Teflon $= \sqrt{2.1} = 1.449$

From these calculations $\frac{\lambda \text{coupling}}{4}$ at 432 MHz is 4.73 inches. With an Xacto knife cut two pieces of line 8.73 inches long and carefully bend them so that they form the shape shown in **Fig. 2A.**

Clamp the bent coax into the vise and file away the copper jacket taking care that the filed surface is smooth and flat. A belt or stationery disc sander works well too. A cross section of the filed piece should look like **Fig. 2B.** Next fit the two pieces together so that a cross section would look like a figure 8 and secure in a vise. Heat with a soldering gun only. Do not use a torch. Avoid excessive heating. Flow solder between the two lines as shown in **Fig. 2C.** The "arms" can now be bent into any convenient configuration provided enough allowance is made at the ends for connector assembly. A good rule to follow is a minimum bend radius of half an inch although a quarter inch radius is permissible. The arms should be approximately two inches long.

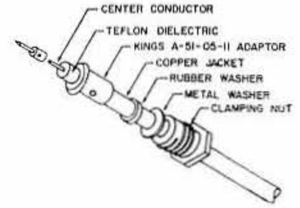


Fig. 3. Use of Kings A-51-05-11 adapter for using GR-141 with standard BNC connectors.

RG 141 has the same cross section as RG 58/U *without* the vinyl jacket therefore any connector that will accept RG 58/U can be used on RG 141 provided a sleeve is made up to make a snug fit in the clamping nut. A special adaptor is made by Kings for this purpose and sells for 45 cents. The connector assembly is shown in **Fig. 3.** Three RG 88E/U and one RG 89C/U connectors were used on the coupler shown in the photo.

Fig. 4 gives the measured directivity and coupling for this type of directional coupler at both 70 and 23 cm. You can see that performance is quite satisfactory.

Fig. 5 lists a number of applications for a directional coupler. The detectors in the measuring instruments should be suitable for use at 500 or 1300 MHz.

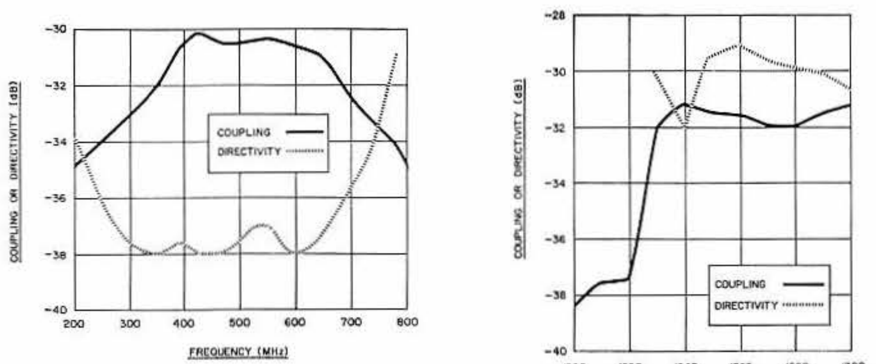


Fig. 4. Coupling and directivity for a directional coupler similar to the one discussed in the text. This device used a coupling wavelength of 4.635 inches rather than the 4.73 inches specified in the text. The only effect of the longer wavelength is to center the curves on 432MHz instead of about 500 MHz.

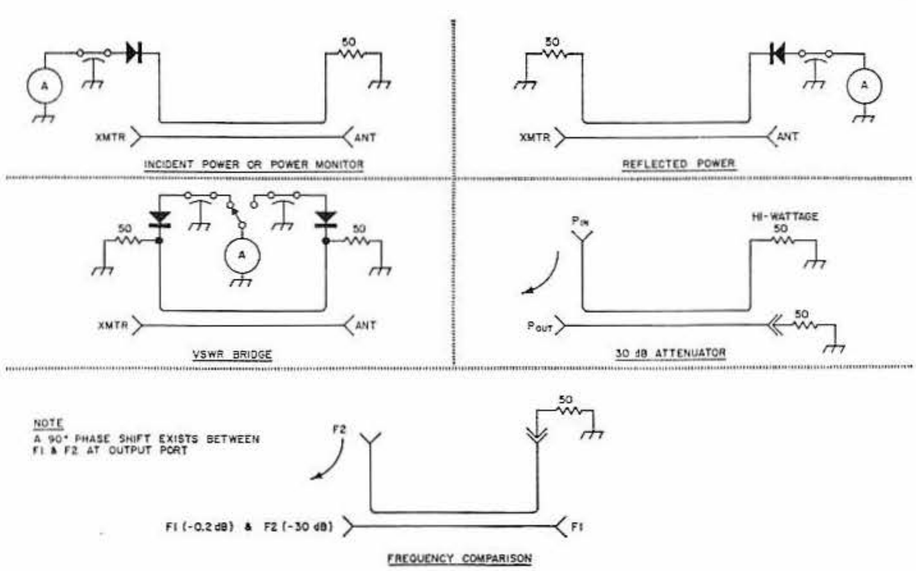


Fig. 5. Applications of the directional coupler described in the text. Unlike most pieces of ham-made test equipment, this one is good at 450 and even 1300 MHz.

A SLOTTED LINE FOR 1250 MHz

Silas Smith WA8CHD

The SWR bridge is a very useful—and sometimes badly neglected—tool. Especially on 1250 mc with only two or three watts of power, you should measure your SWR and do something about it if necessary. I recently joined the 23 cm boys, though I have only worked 1234 mc so far. My first attempt to communicate with W8VKQ on the other end failed but after two evenings of diligent work with a meagre amount of test equipment we made contact. It would have been a lot easier with test equipment good in the 1250 mc range since most hams are not equipped to measure frequency and adjust their rigs at these frequencies.

After that experience, I made the slotted line indicator described in this article. The cost is next to nothing and it's easy to build, but it does a good job. The unit is built around a one inch thin wall copper tube 10¼" long (Fig. 1). This tube has a ⅛" slot cut lengthwise for 7½", about ¾ wavelength at 1250 mc. This is long enough to get a fair sampling of the standing wave or null points.

Three other pieces of 1" copper pipe are needed. Two are 5/16" long and one is 1⅜" long. The two 5/16" pieces each have ¼" cut out and are reshaped to fit inside the 1" tube. These two pieces were each soldered to 1/16" plates as in the detail in **Fig. 1.** This process makes two cup-like structures which should

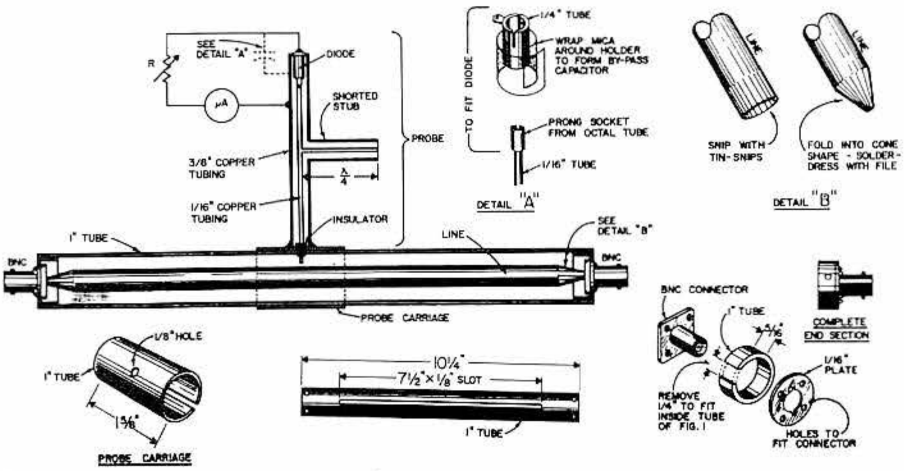


Fig. 1. The slotted coaxial line and probe for 1215 to 1300 mc described in this article.

fit within the end of the 1" pipe. Drill nine holes in each cup: four holes for attaching the cup to the slotted line, four to fit the BNC connector mounting plate and one ⅜" hole to pass the main body of the connector. File two notches for the connector ears. You can fasten the cups to the slotted tube with small sheet metal screws, threaded holes or nuts soldered to the back of the holes.

The 1" x 1⅜" piece of pipe is for the probe carriage. It is cut lengthwise on one side, slipped over the 1" tube, centered, and a ⅛" hole drilled through it over the slot in the 1" tube.

The probe is built from ⅜" and ⅛" brass tubing from your hobby shop. At the probe end is an insulator from a coax fitting and on the other end is a jack made from an octal tube socket. A small piece of ¼" brass tubing is used to make the diode socket (see detail A). A piece of 22 gauge wire is inserted in the probe end of the 1/16" tubing and soldered. A 1N21 diode works very well.

Use **Fig. 2** to choose the proper size for the line in the center. Each end of this line should be tapered and soldered to the coax fitting as in detail B. The center conductor should be 7/16" for 50 ohms or 5/16" for 73 ohms.

The meter used should have a range that permits a full scale reading and should be calibrated with some scale.

Uses: Measuring frequency

Frequency can be measured with the slotted line in two ways: the distance between null points at one half wavelength ($\lambda/2$) or the distance between peaks. See **Fig. 3.** Measuring between the nulls is preferable since the peaks are very broad. If your line is flat, the peaks and nulls may be very small, so you may have to induce a mismatch in the line. Likewise, you may have to induce a mismatch to get the two nulls to fall within the 7½" of the line. The easiest way to induce a mismatch is a short in the line.

Measure the distance between the nulls carefully with a centimeter rule. Twice this distance divided into 30,000 will give you your frequency in megacycles. It would be a good idea to check this against a standard or at least avoid operating too close to the edge of the band.

Measuring VSWR

Measuring voltage standing wave ratio (VSWR) with the slotted line is easy, too. We are looking for a ratio of E_{min}, the minimum voltage on the line, and E_{max}. The ratio:

$$\frac{E_{max}}{E_{min}} = \text{VSWR}$$

However, there is a slight complication of vectors in E_{max} and E_{min}, so that to find them, you must first determine the highest voltage read on the meter, E_1 and the lowest voltage read on the meter, E_2 with the same setting of the shunt resistor, as the probe carriage is slid along the line. Now, $E_{max} = E_1 + E_2$ and $E_{min} = E_1 - E_2$ so that

$$\text{VSWR} = \frac{E_1 + E_2}{E_1 - E_2}$$

An even simpler method is to set the meter to full scale (100) at the highest reading, and reading the VSWR directly from **Fig. 5.**

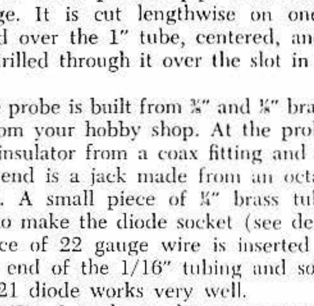


Fig. 2. Ratio of outer tube to inner line for various impedances.

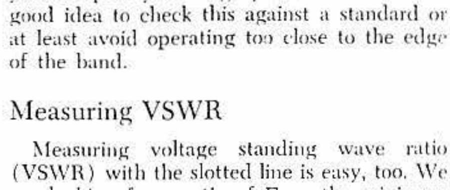


Fig. 3, Left. Measuring frequency. Fig. 4, Right. Measuring VSWR.

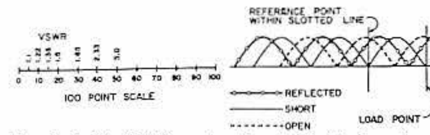


Fig. 5, Left. VSWR scale. Fig. 6, Right. Impedance measurements.

Impedance measurements

It's a little harder to measure impedance, but even it's not bad if you do it step by step. First, consider the high impedance on your line when your antenna is open or shorted. Perhaps you don't think of it as a change in impedance. This is what we are looking for. Remember that there is a definite relationship between impedance and frequency. **Fig. 6** shows the voltage relationship between a short and open. On a short set the probe for a null point, usually the first null from load end of the slotted line. This will be our reference point. You will note that when the load point is open there is a shift of 90° or a quarter wavelength either side of the reference point. This adds up to one half wavelength. Any impedance between infinity and zero ohms will lie somewhere along the half wavelength of the line. It will be noted that an open is equidistant from the reference point toward the generator and toward the load, however the line has moved toward the load (capacitive reactance). To measure this reactance, we replace the load that we measure with a short. We set our probe to the first minimum reading from the load end of the slotted line. Mark this spot with a scribe. This is our reference point. Now we remove the short and add our load under measurement. It will be noted that the voltage has moved upward. Move the probe toward the load. If the voltage goes down, you are heading in the right direction. If the voltage starts to go up change direction toward the generator. Move the probe as above to the new null point and note the direction that the probe has been moved.

Here's a step-by-step example. First, you'll need the frequency and wavelength, VSWR, direction of probe, distance between reference point and new null, and impedance of the slotted line.

Let's say as we measured the frequency, the distance between the null points was 12 cm. This is half the wavelength, so the wavelength is 24 cm. The frequency is 30000/24 or 1250 mc.

Let's say we read 80 as a maximum and 20 as a minimum on a point scale in measuring the VSWR:

$$E_{max} = E_1 + E_2 = 80 + 20 = 100$$
$$E_{min} = E_1 - E_2 = 60$$

$$\text{VSWR} = \frac{100}{60} = 1.66$$

Or set E_1 to 100 by adjustment of R, then E_2 would read 25 on the meter, a VSWR of 1.66 by **Fig. 5.**

As in **Fig. 6,** the probe was moved toward the load.

Let's assume the distance from the reference point to the new null was 2 cm. What part of a wavelength is 2 cm? Wavelength is 24 cm, so $2/24 = .083$ wavelengths.

This is a movement of .083 wavelengths toward the load.

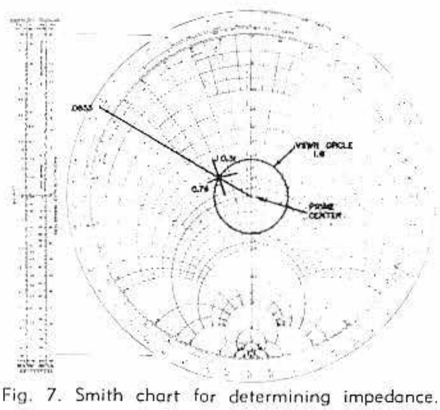


Fig. 7. Smith chart for determining impedance.

The slotted line used has an impedance of 50 ohms.

We are now ready to plot this information on the Smith chart (**Fig. 7**, better get out your magnifying glass).

Draw the VSWR circle at the prime center with a radius of 1.6.

Draw a line from .083 wavelength toward the load from the prime center.

At the intersection of the circle and line, follow the constant resistance circle to .74 and the capacitive reactance circle to .31. Our load impedance is then:

$Z_L = Z_o\ (.74 - .31j)$
$Z_L = 50\ (.74 - .31j)$
$Z_L = 37 - 15.5j$

Well, there are some of the things your slotted coax line can do besides telling you that you're on the air. A commercial version would cost $750. I guarantee that you'll get your dollar's worth out of this one as it costs less than $1 to build. I hope that it helps you get on 1250 mc.

SOME DIRECTIONAL WATTMETERS AND A NOVEL VSWR METER

P. G. Martin G3PDM

Most conventional reflectometers cannot be used for accurate power measurement because their sensitivities are frequency dependent. This is due to the use of combinations of reactance and resistance in the sampling circuits which detect the transmission line current and voltage.

This basic problem can be solved by the use of conventional lumped components instead of the distributed parameters of a transmission line. The line voltage can be sampled by two resistors or two capacitors used as a voltage divider, rather than one resistor and some distributed capacitance. The line current can be monitored by a properly designed current transformer instead of an inductance and resistance. High frequency current transformers consist of primary and secondary windings on a ferrite or iron dust toroidal core, with a low value of load resistance across the secondary winding.

All SWR bridges and directional wattmeters need to generate two dc voltages proportional to the forward and reflected voltages or currents of the transmission line. To achieve this one has either the current detector or the voltage detector providing two antiphase signals so that addition and subtraction can be performed.

A Frequency-Independent Directional Wattmeter

M. B. Allenson G3TGD, has designed a wattmeter using the above principles, where the low resistance in the current transformer secondary circuit is split into two equal parts. The center connection is taken to the voltage sampling point so that sum and difference voltages are available at the ends of the transformer secondary winding, see Fig. 1.

With two meters, this circuit can be used as a versatile calibrated directional wattmeter over the freqnecy range 100 kHz to 70 MHz, with an accuracy of about 10 per cent. Precise calculations of SWR and transmitter efficiency can be made.

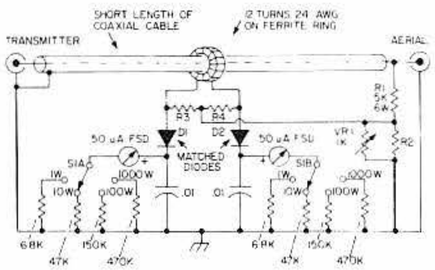


Fig. 1. Circuit of the basic frequency-dependent directional wattmeter due to G3TGD. The two meters indicate forward and reflected powers.

Maximum sensitivity with a 50 μA meter is less than five milliwatts, but with the multiplier resistors specified in Fig. 1, full scale deflection corresponds to power of 1, 10, 100 and 1000 watts. Calibration is non-linear, because the instrument samples

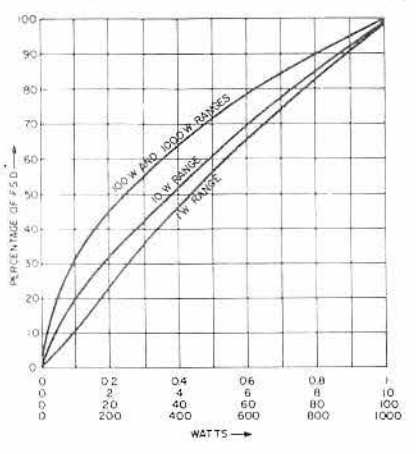


Fig. 2. Calibration curves for the instrument described in Fig. 1.

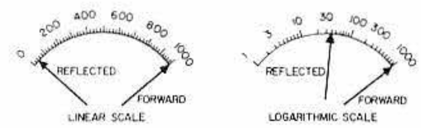


Fig. 3. Linear and logarithmic scales. The inherent advantages of the logarithmic form are immediately obvious.

voltage, and power is proportional to voltage squared.

Unfortunately, two transmission line impedances are in common use in coaxial systems: 50Ω and 75Ω. As it is not possible to design instruments whose sensitivities are independent of line impedance, some component values must depend on the impedance in use. For simplicity, only one of the voltage driver resistors need be changed, but instrument calibration will be different. By changing the current transformer resistors as well as one of the voltage divider resistors, the calibration is the same for both line impedances. This technique has been adopted here, and the calibration curves in Fig. 2, are correct for 50 or 75Ω lines provided the resistor values in Table I are used.

The Logarithmic Wattmeter

The basic instrument can be simplified by including a logarithmic network so that the power range switch is redundant and a single meter scale can be used for powers from, say, one watt to 1000 watts. A logarithmic scale has the 1, 10, 100 and 1000 watt points equally spaced (see Fig. 3).

The advantage of a logarithmic instrument is that one can measure very low reflected powers and very high forward powers simultaneously with the same percentage accuracy, without having to switch meter ranges.

It is simple to add a reasonably accurate *wide-range* logarithmic network to the meter in Fig. 1 (see Fig. 5). The basis of its

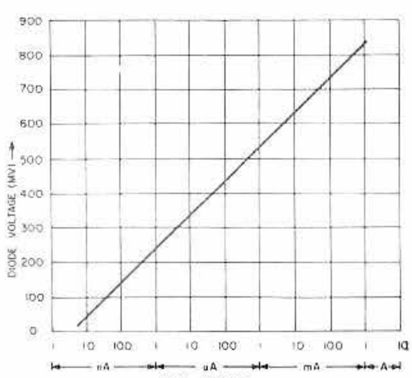


Fig. 4. Smoothed experimental plot of the current /voltage characteristic of a 1N4002 silicon junction diode, showing its logarithmic properties.

operation is that the voltage dropped across a forward-biased p-n junction diode is proportional to the logarithm of the current passing through it (see Fig. 4). To reduce the potential dynamic range of the circuit, a relatively insensitive meter is used, and a small resistance is added in series with the logarithmic diode to restore a logarithmic form to the scale (see Fig. 6).

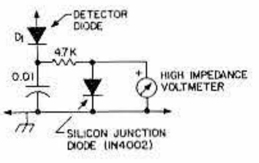


Fig. 5. Basic wide-range logarithmic converter.

An experimental logarithmic wattmeter is shown in Fig. 7. Figure 8 gives the calibration scale for 50 or 75Ω lines, provided the correct resistors are used (Table I).

A Direct-Reading SWR Meter

A particularly useful device would be an instrument giving a direct measurement of the standing wave ratio on a transmission line, independent of the absolute power levels or the frequency in use. Such an instrument, with its single meter, would be ideal for incorporation into transmitters and transceivers (especially with the physically small sampling circuits associated with it).

The swr can be expressed in terms of the forward and reflected voltages according to:

$$\text{swr} = \frac{E_f + E_r}{E_f - E_r} \qquad (1)$$

We wish to generate this function electronically, so that outputs of the two detectors can be used to generate a meter current proportional to SWR. This would be rather tedious, though not impossible.

Conveniently, manipulation of equation (1) shows that:

$$\frac{E_f}{E_r} = \frac{SWR + 1}{SWR - 1} \qquad (2)$$

which although not proportional to SWR, is a mathematical function of it only. Electronic division of E_f by E_r is easily done by taking logarithms and subtracting. That is:

$$\log \frac{E_f}{E_r} = \log E_f - \log E_r$$

Table I

	Ω	Ω
Line impedance	50	75
R3 and R4	27	33
R2	220	180

Values for R2, R3 and R4 to be used in 50 and 75Ω transmission lines.

In Fig. 9, the two silicon diode voltages are proportional to the logarithms of their currents, which in turn are proportional to the forward and reflected voltages. The two diode voltages can be subtracted directly by connecting a meter between them, rather than from each one to chassis.

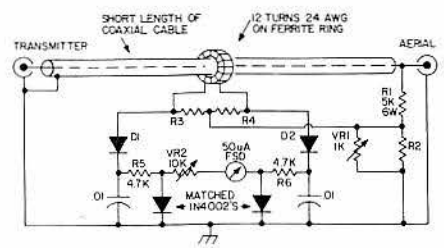


Fig. 6. Circuit of the logarithmic directional wattmeter. D3 and D4 are matched (see text).

The meter cannot be calibrated linearly in SWR, because of equation (2), and because the circuit does not take anti-logarithms after subtracting the logarithms. The outcome of this is beneficial: the SWR meter is increasingly sensitive as the standing wave ratio approaches 1:1. This is where one wants most sensitivity: to make the final

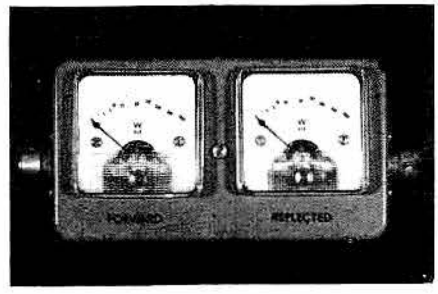


Fig. 7. An experimental logarithmic wattmeter.

adjustments to aerial arrays, to measure the variations in SWR over a band, and so on. Fig. 10, shows a calibration curve for SWR meters. Naturally the meter sensitivity cannot be completely independent of the power level in use. Accuracy falls when the reflected power is less than about half a watt (this corresponds to an SWR of 1.05:1 when the forward power is 1 kW).

A differential amplifier could be added to the circuit of Fig. 9, to enable a less sensitive meter to be used.

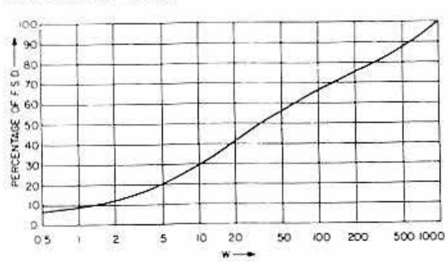


Fig. 8. Calibration curve for logarithmic wattmeters.

Construction of the Instruments

Layout of the sampling circuits is fairly critical, see Fig. 11. The input and output sockets should be set a few inches apart, and connected together with a short length of coaxial cable. The coax braid must be grounded at one end only, so that it acts as an electrostatic screen between the primary and secondary windings of the toroidal transformer. Twelve turns of 24 AWG enamelled wire, equally spaced around the circumference of the ring, form the secondary winding. The primary is formed by simply threading the ring onto the coax.

A suitable ferrite ring is the Mullard FX1596, made in England, although other types are suitable. The FX1596 has an outside diameter of half an inch, and is designed for wideband rf applications between 5 and 20 MHz. The main requirement is that the ferrite material should maintain a high permeability over the frequency range in use.

Other components in the sampling circuits should have the shortest possible leads. R1, R2 and R must be non-inductive solid carbon types: for high power levels (about 100 watts) R1 should consist of two or three 2 watt carbon resistors in parallel. VR1 should be a miniature skeleton potentiometer to keep stray reactance to a minimum, although it may be dispensed with by trying various fixed resistors for R2 until the reflected indication under matched conditions is zero.

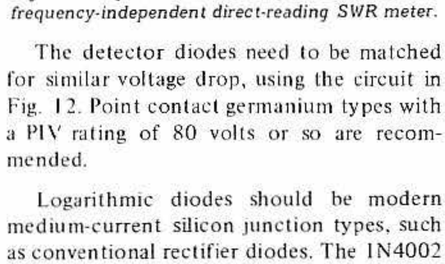


Fig. 9. Complete circuit for a power-independent, frequency-independent direct-reading SWR meter.

The detector diodes need to be matched for similar voltage drop, using the circuit in Fig. 12. Point contact germanium types with a PIV rating of 80 volts or so are recommended.

Logarithmic diodes should be modern medium-current silicon junction types, such as conventional rectifier diodes. The 1N4002 is specially recommended for its good logarithmic properties. Log diodes should also be matched with the circuit in Fig. 12.

The 0.01 µF decoupling capacitors should be a disc ceramic type.

In designing a toroidal transformer different to that specified, several factors should be borne in mind. As the number of secondary turns increases, the self-capacitance rises and causes the response to fall at high

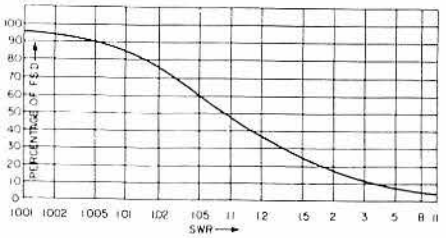


Fig. 10. Calibration curve for SWR meters of the type described in Fig. 9.

frequencies. Failure of this nature causes the reflected power indication to rise; in other words the directivity of the instrument falls. If the 27Ω resistors are raised appreciably in value, the instruments will eventually become frequency sensitive.

The ratio of the voltage sampling resistors (R1 and R2) in the HF designs is determined by the sensitivity of the current sensing circuit, and the two sampling voltages must be equal in magnitude under matched conditions. VR1 provides fine adjustment of the ratio. Absolute values of the resistors can be varied considerably, bearing in mind that as their values increase the stray capacitance across them may need to be compensated for.

Useful Equations

Let the line current be I amps, the line voltage be V volts, and the characteristic impedance of the transmission line be Z_O. Then $V = IZ_O$.

If the current transformer has a ratio of 1:n, and each of the resistors in its secondary circuit has a value of RΩ, then the rf voltage across each of them is given by:

$$V_{(i)} = \frac{IR}{n} \qquad (3)$$

The voltage detector output is obviously

$$V_{(v)} = \frac{VR_2}{R_1 + R_2} = \frac{R_2}{R_1 + R_2} IZ_O$$

Which is, to a good approximation,

$$V_{(v)} = \frac{R_2}{R_1} IZ_O \qquad (4)$$

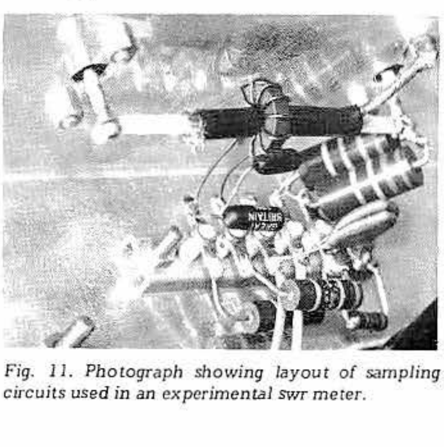


Fig. 11. Photograph showing layout of sampling circuits used in an experimental swr meter.

The main design equation for all the HF instruments is therefore:

$$R_2 = \frac{R.R_1}{n.Z_O}$$

where the value for R2 includes the effect of VR1, if fitted.

The dissipation of some of the components specified is quite high. For those planning different circuits, the following equations express the dissipation of R1 and the current transformer resistors R:

$$W_{(R1)} = \frac{Z_O.W}{R_1} \quad \text{watts,}$$

where W is the transmitter output power.

$$W_{(R)} = \frac{W.r}{n2.Z_O} \quad \text{watts.}$$

In the instruments described, $W_{(R1)}$ is about 5 watts, and $W_{(R)}$ 2 watts for a transmitter power of 500 watts.

Calibration

If any of the instruments are built exactly as described, and used in systems of the correct impedance, the calibration given in Figs. 2, 8 and 10 will be sufficiently accurate for most purposes. For those designing their own circuits, the following procedure is recommended.

Test equipment needed includes a high power rf source (a transmitter) and an rf voltmeter. The instruments can be calibrated with less accuracy without the rf voltmeter. The wattmeters are calibrated by feeding power through the meter into an appropriate dummy load (50 or 75Ω). VR1 is set for minimum reflected power indication, and the power scale is marked according to the rf voltage appearing across the load. If an rf voltmeter is not available, a peak-reading type can be made with a diode, capacitor and dc voltmeter. As the detector output is equal to the peak rf voltage applied to it, equation (4) leads to:

$$V_{(det)} = 2.8\ V\ \frac{R_2}{R_1} = 2.8\sqrt{WZ_O \frac{R_2}{R_1}}$$

It would be difficult for most amateurs to obtain sufficient high power carbon resistors to calibrate an SWR meter by means of deliberate mismatching. An indirect method is therefore recommended.

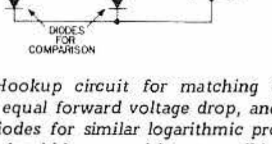


Fig. 12. Hookup circuit for matching detector diodes for equal forward voltage drop, and silicon junction diodes for similar logarithmic properties. The meter should be as sensitive as possible (say 50 μA fsd), and should not deflect appreciably as the voltage is varied between zero and nine volts.

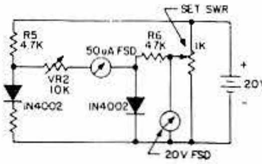


Fig. 13. Circuit used to calibrate SWR meters(see text).

Disconnect R5 and R6, Fig. 9, from the detectors, and connect them instead as shown in Fig. 13. One voltage is fixed at about 20 volts, and the other is varied between zero and 20 volts. The ratio of these voltages corresponds to a definite SWR which can be determined from equation (1). Before carrying out this procedure, however, VR2 should be set for full scale deflection of the meter under matched conditions at the highest power level to be used.

Conclusions

All of the instruments described in this article have been tested under actual operating conditions, on all amateur bands between 1.8 MHz and 30 MHz. Power levels used varied from 100 to 1200 watts. With the components specified, the instruments will sustain power levels well above the kilowatt level for periods of tens of seconds.

It is hoped that by introducing frequency independent directional wattmeters, one will be able to make useful comparisons of absolute power levels and accurate assessments of standing wave situations. The logarithmic scales are an added convenience, and the direct-reading SWR meter offers a saving in meters.

SWR BRIDGES USING ZERO-CENTER METERS

John Schultz W2EEY/K3EZ

The basic coaxial cable swr meter, which samples both the forward and reflected voltages on a transmission line, is an essential instrument in setting up an amateur station. Although a low transmission line swr in itself doesn't guarantee that an antenna system will work, knowing what the swr is remains an essential bit of information in evaluating the status of the transmitter/antenna interface.

The virtues of the usual coaxial line swr meter – economy and simple circuitry – are offset by the awkwardness involved in using the instrument: that is, switching back and forth between "forward" and "reflected" switch positions and adjusting a sensitivity control for sull-scale deflection in the forward position. This awkwardness of operation is partly relieved by dual-instrument swr meters so the forward/reflected switch is no longer necessary – but the cost of the instrument increases. The awkwardness of

operation can be completely relieved by special dual movement meters with crossing pointers and/or special circuitry, but then the cost really soars.

Another approach is the usage of some different circuitry to detect the swr which can then activate a zero-center meter so one can peak up the antenna coupler, etc., for minimum swr on a transmission line with the same ease as one tunes an FM entertainment receiver for a zero-center reading on the discriminator meter. In the end analysis, practically no line is set up for any specific swr, but simply for the lowest swr that can be achieved. So, why not make the process as simple as possible? Circuitry to do this has actually been available for many years and was especially developed for use with the automatic servo-tuning of military transmitters. The zero output when tuning conditions were correct, and the plus or minus output when they were not, allowed, after sufficient power amplification, the activation of motors to tune transmitter PA task circuits, coupling circuits, etc. Now, with the economical availability of toroids and imported zero-center meters, zero-center swr type circuits can be applied to amateur usage and meet the criteria of being easy to construct and economical. They offer a real challenge to the conventional type of swr meter, especially when one is using a multiband antenna and tuner arrangement, or just leaves an swr meter in a transmission line to verify that the line swr is holding constant. In the former case, one usually knows the approximate transmitter/tuner settings on each band, and the swr meter is used to peak up the adjustments. Such peaking-up, as mentioned before in the case of an FM receiver, is certainly facilitated by just having to look at a zero-center meter. In the latter case, a zero-center meter will more readily reveal slight changes in transmission line swr from an established norm. Perhaps the only place where a conventional swr meter is still to be preferred is when one is

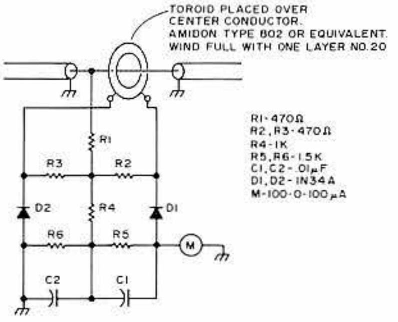


Figure 1.

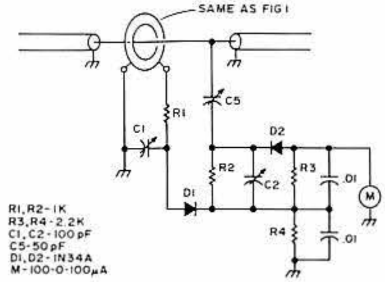


Figure 2.

dealing with experimental antennas where extreme swrs exist and a conventional swr meter can help to more quickly obtain "ballpark" antenna coupler or loading coil settings. The zero-center type circuits operate on a slightly different basis than the conventional swr meter circuits, and just a brief review of transmission line operation will be helpful to understand the different basis for the functioning of the two types.

If a transmission line is attempting to deliver power to a load, both voltage and current values exist along the line. If the antenna load impedance is resistive and equals that of the line impedance, all the power feed into the line reaches the antenna less any power loss in the line itself because of the line's inherent loss. If the load is not equal to the line impedance or reactive, part of the power the line tries to deliver is rejected by the load and reflected back along the line. This sets up standing waves of voltage and current which are not in phase with the original voltage and current waves the transmitter is trying to "pump" into the line.

Conventional swr meters sample a portion of the voltage or current wave traveling towards the load and a sample of that traveling back from the load. The relative amplitude of the two samples is the swr and, of course, the desired condition is that there be no reflected wave from the load. If there is no reflected power from the load, the line is often referred to as being "flat." This term is a bit misleading. Although the reflected power may be zero under matched conditions, the power flowing to the load via the line will still set up normal sine wave distributions of voltage and current along the line.

Another way to sense that the load is matched to the line is to determine first of all that the phase difference between the voltage and current on the line is zero and that the ratio of the in-phase voltage and current is correct for the impedance of the line being used. If there is no reactance present in the load, there will be no phase difference between voltage and current, as in any ac circuit feeding a resistive load. If the load is not only non-reactive but also of the correct resistance, the ratio of voltage and current on the line will have a definite relationship correct for a given line impedance. The zero-center meter circuits are designed to monitor both of these line conditions.

Practical Circuits

Two separate circuits are used to monitor the line conditions just described. One could switch a separate zero-center meter between the two line monitor circuits but with imported zero-center meters available for as low as $1.50, it is hardly worthwhile to do so. (A good source of the 100-0-100uA meters needed is Edlie Electronics, 2700 Hempstead Turnpike, Levittown NY 11756. Their meters with order number DA798 or DA792 cost only $1.50 but they have a $7.50 mail order minimum.) Also, for many installations, it is not necessary to use both circuits. For instance, in a home installation feeding a set of various fixed antennas, it would probably be of primary interest to have the impedance monitor circuit (voltage/current ratio). Once the antennas have been set up and operate satisfactorily, one would primarily just be interested to know that some impedance condition on the line has not changed. In a mobile installation, where some reactance cancelling L or C needs to be adjusted with frequency changes, it would be of prime interest to have the phase monitor circuit once the installation has been initially set up for a correct impedance match, and the reactance cancelling component only needs adjustment during actual operation.

Phase Monitor

Fig. 1 shows the circuit of the phase monitor. It is a basic discriminator circuit. The voltage on the transmission line to ground is sampled via R1. The current on the line induces a voltage in the windings on the toroid placed in the line which, of course, is 90° out of phase with the voltage sample. The voltage proportional to the line voltage is divided across R1 and R4 (C1 and C2 are rf bypass capacitors). The voltage proportional to line current (across the toroid winding) is divided between R2 and R3. Referenced to the center point of R2 and R3, these voltages are 180° out of phase with respect to each other and either one is 90° out of phase with respect to the voltage across R4. The voltages across R2 and R4 are rectified by D1 and, because of the diode

polarity, produce a voltage with the polarity indicated across R5. Similarly, R3 and R4 and D2 produce a voltage of opposite polarity across R6. When the transmission line current and voltage are in phase, the voltages across R5 and R6 are equal and opposite, and the resultant voltage output which drives the meter is zero. For an out-of-phase condition, some output voltage exists whose magnitude indicates the amount of the phase difference and whose polarity would indicate whether the line voltage leads or lags the line current.

One could actually calibrate the output meter for different magnitudes and directions of phase difference, but this would be very tedious and not of real use for just checking the adjustment of a line for reactance cancellation. The only calibration that has to be checked is to excite the circuit into a resistive dummy load and to be sure that the zero-center feature works. If it does not, it indicates that some unbalance has been introduced during construction or some of the components (R2/R3 and R4/R5) are not closely enough matched. If the meter excursions off zero center become too violent with a high power transmitter, some additional resistance can be introduced in series with the meter to limit the maximum current flow.

Impedance Monitor

Fig. 2 shows the circuit of the impedance monitor, which is also a form of discriminator circuit. Samples of the transmission line voltage and current when they achieve the desired ratio produce an output voltage from the circuit which is zero. As in the previous circuit, a toroid placed around the center conductor of the transmission line develops by transformer action a voltage proportional to the line current. A sample of the line voltage to ground is taken via the variable capacitor C5. Unlike the previous circuit, both the sampled voltages are rectified, producing voltages across load resistors R3 and R4, without paying any attention to the phase differences between the sample voltages. It is only the amplitude of the sample voltages which determines the amplitude of the voltage across R4 (for the line voltage) or across R3 (for the line current). Because of the diode polarities, the voltages across R3 and R4 are of opposite polarity. They will cancel when equal, producing zero output voltage, and since C5 is variable, this condition can be set to occur at any desired line voltage to current ratio.

The difficulty with this circuit is that the sample voltages generated by the toroid transformers and the C5 coupling are frequency dependent. The rest of the components in the circuit (R1/C1 and R2/C2) are there to help eliminate the frequency sensitive output of the coupling elements over a reasonable range.

C5 is set with C1 and C2 at mid-range to provide a zero voltage output from the circuit on 20m when the line is terminated in a resistive load equal to the line impedance. Going to 10m, C2 is adjusted to restore balance and on 80m, C1 is used to restore balance. The adjustment has to be gone through several times before a good balance is achieved over the entire HF range. It would be possible to calibrate the meter with different value load resistors for different swrs. For high value loads, the meter would move off center in the opposite direction for low value loads. But, such calibration would only hold true for non-reactive loads.

Construction

Many conventional swr bridge circuits have been described over the last year or two in amateur literature where a toroid transformer, rather than a parallel wire to the center conductor of a coaxial line, has been used as a pickup element. The construction of such units applies equally well to the circuits shown here. It is only the circuitry following the pickup element that is really different, plus the added R1 pickup in Fig. 1, or the C5 pickup in Fig. 2. Note that it doesn't matter on which side of the toroid these pickups are placed. However, as in any rf circuit, all leads must be kept as direct and as short as possible. The circuits shown are for the HF range, but by changing the toroid and values of the bypass capacitors, they can be extended, by experienced experimenters, into the VHF range.

Chapter II

How to Measure RF Impedance

THE ANTENNASCOPE – AN EFFECTIVE TOOL

W. R. Carruthers VE3CEA

There are two types of antennas, commercial and amateur. A commercial antenna is generally designed for one frequency, has many acres of ground around it, no obstructions and miles of heavy copper cable buried underground to provide an "effective" ground. These antennas work as designed – very well. The amateur antenna, on the other hand, is just that – an amateur design and construction.

This antenna is subject to all ills, roof tops, buildings, trees, TV masts, house electric wiring, telephone wires and what not. It's a wonder they work at all! But they can be made to work and thousands of amateurs make them work. They make them work by pruning or lengthening the feeder cable and by using an antenna coupler. These are always empirical steps, the "let's cut and try and see what happens" method. How much better it would be, and a time saver too, if we tested our antenna systems electrically and *knew* what was happening and then could take intelligent action to put the whole antenna system into resonance.

This fact is well known – an antenna can only accept power and radiate properly when it is operating at its resonant frequency. This is no problem for the commercial people who operate at one frequency. The amateur, however, wants to "roam the band" and may wish to operate over frequencies hundreds of thousands of cycles wide, even megacycles wide. How can he do this with a fixed antenna system? The answer is, he can't! But he can construct an antenna system for a certain frequency and take the penalty of reduced radiation when he moves far away from it. However this actually works very well, because each amateur has his own particular part of a band in which he likes to operate – and his friends tend to stay there too. On this particular spot, the amateur works diligently to "put out a good signal."

The question arises – how can we make sure our antenna system is radiating well at the particulaf frequency we wish to use? One answer is to use electrical test equipment to show us what is happening on the whole antenna system, which includes the antenna and the feed line.

One of the most useful devices for this purpose is the rf bridge, generally called the Antennascope. It is a simple device, inexpensive to construct and very effective in results. It is usually powered by a grid dip oscillator. Such bridges should be used at the junction of the feed line and the antenna and will show the resonant frequency of the antenna itself and the radiation resistance at the feed point.

Making such measurement up in the air is a difficult thing for the average amateur and impossible for those whose antennas are supported at the ends. If we are willing, however, to accept a small degradation in results, we can use the *rf* bridge at the station end if we have a half wave, or multiple of a half wave, feed cable. At every half wave point on a feeder cable the voltage and current vectors are in phase, which simply means that the electrical condition seen at the end of the cable is repeated every half wavelength in the cable. We can use the *rf* bridge then, at the station end of the feed line, if we are willing to agree that the results will not be 100% but reasonably close to it. The results will be affected by all the various factors that affect amateur antenna resonance and these effects may give us some peculiar results, but they can be overcome and the final results may be quite valuable to us.

Let me give you an example to illustrate what I'm talking about and to show you how effective the use of the *rf* bridge can be: –

A friend of mine constructed a 40 meter inverted V antenna, held at the feed point 40' up on his beam tower, 66' legs down to supports which held the ends about 8' off the ground. Feed line was 100' of Twin Amphenol cable, velocity factor .68. The antenna was difficult to feed, swr was high, radiation was poor. He asked me to have a look (electrical) at it. I took my grid dip meter, *rf* bridge and vtvm.

The first thing done was to check the feed line length. 1/2 wave length at 7.1 MHz was 492 x .68/7.1 or 47.1 feet. Two 1/2 wave lengths (to get into the station) would be 94.2 feet.

The first conclusion was that the feed line was 5.8 feet too long.

Next Test No. 1 was made using the *rf* bridge with results as shown in **Fig. 1**, the results being shown in table form and also plotted in graphical form.

It was obvious from this graph that the antenna system was resonating outside the

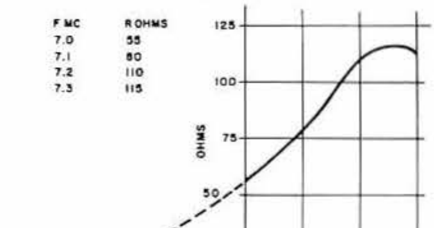


Fig. 1. 100' Feedline Test No. 1.

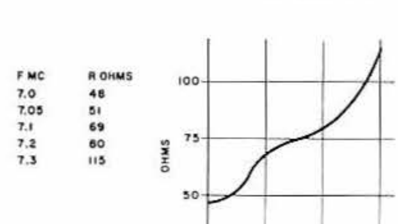


Fig. 2. 94.2' Feedline Test No. 2.

band as shown by the dotted lines. This test was repeated and the results were taken down to 6.4 MHz. They showed the system to be resonant at 6.6 MHz.

Test No. 2 was made next using the feed line cut to 94.2 feet. **Fig. 2** shows the results.

It was obvious the resonant point of the system was rising.

Test No. 3 was made next, cutting the feed line to 91.2 feet long. **Fig.** 3 shows the results.

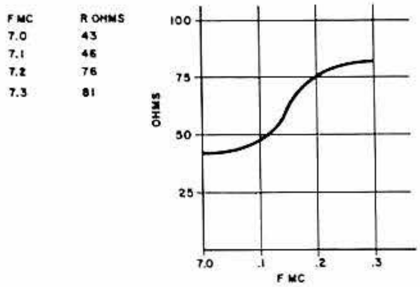


Fig. 3. 91.2' Feedline Test No. 3.

The resonant point was rising, but not far enough yet.

Test No. 4 was made using the feed line cut to 88.2 feet long. **Fig. 4** shows the results. It was obvious that we were very

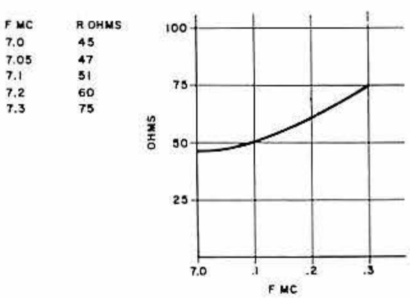


Fig. 4. 88.2' Feedline Test No. 4.

close to the resonant frequency of 7.1 MHz which my friend wished to use.

Test No. 5 was with 85.2 feet in the feed line. **Fig. 5** shows the results.

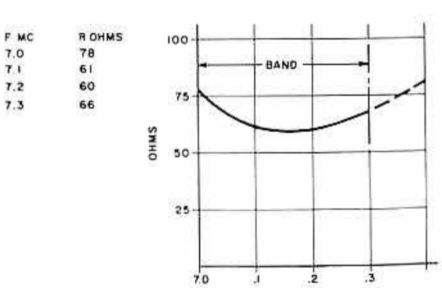


Fig. 5. 85.2' Feedline Test No. 5.

Test No. 6 was with the transmitter (300 watts CW) and antenna coupler connected. There was no trouble in loading and no trouble in balancing the coupler to obtain an swr of 1 to 1 ratio.

The results on the air were interesting, 5/9+ reports to the Eastern half of the U. S. A., 5/8 reports to Germany etc. *Conclusion:* The results shown above are not precise, nor can they be expected to be precise. There are too many unknown factors entering the electrical picture, such as those which required a shortening of the feed line, in this example, to somewhat less than a half wave length. But the bridge showed us the overall picture and suggested what was required to be done. The on-the-air results show that it was giving us a good picture and a result that was very satisfactory for my friend's needs.

Why not construct an *rf* bridge and check you own antenna system? I suggest it will pay off and be very informative to you, showing you what your antenna system looks like electrically and what to do to bring your whole system to the resonant frequency you wish to obtain. . . . VE3CEA

HOW TO BUILD AN ANTENNASCOPE

Paul Franson WA1CCH

A type of simple bridge used for measuring antenna impedance is called the Antennascope, shown in Fig. 1. This bridge is designed for low power operation – a grid dip meter usually gives plenty of power. It should be built very compactly with short leads. The potentiometer should be of high quality; an Allen-Bradley Type J is fine. The bridge can be calibrated with regular composition resistors. Simply connect the resistors in turn to the antenna terminal and adjust the pot until the meter reading dips to zero. Then mark the value of the resistor by the pot pointer. In use, the meter reading will not null completely except for resistive loads, so it will not read zero for reactive antennas. Nevertheless, the minimum reading will occur at the approximate impedance reading. Remember that all antenna bridges should be used between the antenna and the transmission line.

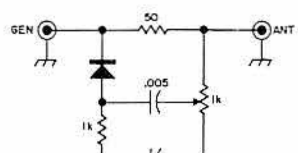


Fig. 1. The Antennascope is a simple antenna impedance bridge. It should be constructed compactly for best high frequency use.

THE MARK III RF IMPEDANCE BRIDGE

Mark Cholewski W6CRT

NEED to measure the input impedance of that new beam? Or maybe to find out just what is the Q of the coils in your final? Or even to determine how much signal is being soaked up by your coax? If you ever want to do these, or any similar jobs, then the Mark III RF Impedance Bridge is the thing for you.

You can build it for a total cost of about $30 (exclusive of sheet metal) and, if you follow instructions closely, it will be accurate to closer than 10 percent throughout its operating range. Unlike the more common resistive-bridge and reflectometer methods of measuring impedance, the Mark III operates equally well at resonance or far away. It will measure both resistance and reactance present in resistors, capacitors, inductors, antennas, and transmission lines at any frequency between 2 and 30 mc.

Before we start into the actual construction of the Mark III, one thing must be emphasized. Accuracy can be assured only if the components, circuit, and parts layout are absolutely duplicated. The original instrument's calibration was obtained through tedious laboratory techniques. If you make any changes, the calibration curves will no longer apply. However, if instructions are followed to the letter you need have no worries about accuracy. A test model, built by W6BJU following these instructions, checked out to 2 percent accuracy at 2 mc and 10 percent at 30 mc.

Construction of the Mark III divides into three major sections: Preliminary metalwork, actual wiring, and calibration. Each will be described separately. Ready? Let's go!

Preliminary Metalwork

1. Cut, drill, and bend to shape from soft aluminum shields S1, S2, and S3 as shown in Figs. C1, C2, and C3.
2. Cut, drill, and tap plexiglas insulators I1, I2, and I3 from bulk rod stock as shown in Figs. C4 and C5. When tapping plexiglas, use water as lubricant.
3. Cut, drill, bend, and solder tubular shields S1A, S2A, and S3A as shown in Fig. C6. Copper or brass may be used; aluminum should be avoided because of solding difficulties.
4. Assemble shielded resistor assembly R2/S4 as shown in Fig. C7. The copper tubing must be drilled out to clear the body of R2. When soldering, hold the assembly in a vise to protect R2 from excessive heat.
5. Cut, drill, bend to shape, and solder box shields S1B, S2B, and S3B as shown in Fig. C8.
6. Drill S5 (a 3x4x6 LMB unpainted chassis box) as shown in Fig. C9.
7. Cut, drill, and bend to shape shield partition S5A as shown in Fig. C10.

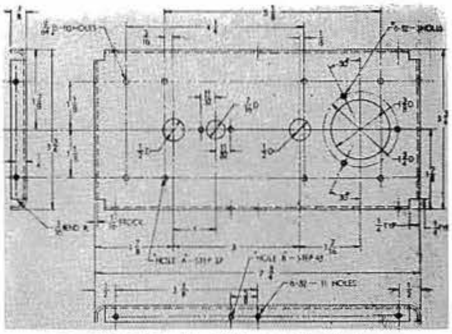
Shielded Transformer

While classified under the "preliminary metalwork" section for reasons which will become obvious, construction of the shielded transformer is the most critical part of the entire project. Before proceeding, read and re-read steps 8 through 24 and be sure that you understand them fully. Take special care when soldering—three transformers were built for the original instrument before a non-shorted one was achieved.

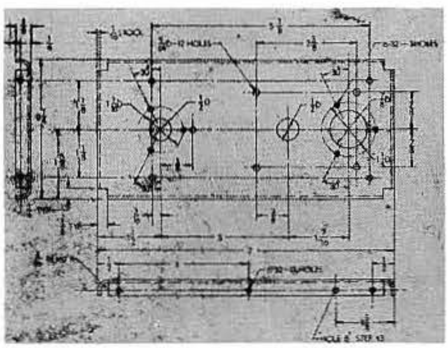
8. Cut to length, drill, and tap transformer mounting insulator I4 from 5/16-inch plexiglas rod.

9. Cut and drill two bobbin-end washers as shown in Fig. C12 and solder them to a length of copper tube as also shown. Then cut halfway through the bobbin with a hacksaw.
10. Pull the shielding from an 18-inch length of RG58/U. Save 8 inches for step 19 and use the rest in step 11.

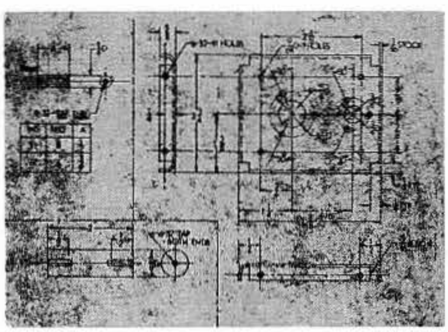
11. Solder one end of the 10-inch shielding into the U-shaped slot on the bobbin end, using an aluminum rod or small drill to keep the inside of the shielding open. It must pass



C1—Shield S1 (1 REQ), Mat'l Aluminum



C2—Shield S2 (1 REQ), Mat'l Aluminum



C4 — Insulators, Mat'l Plexglas rod
C5 — Insulator 13 (8 REQ), Mat'l Plexiglas rod

C3—Shield S3 (1 REQ), Mat'l Aluminum

No. 26 plastic-covered wire. Clean off all metal burrs and solder splatters.

12. Wind 48 turns of No. 26 plastic-covered hookup wire on the bobbin in three lays of 16 turns each. Solder the start of the winding at point A (see Fig. C12) and wind in the direction shown by the arrow.

13. The last turn will end at the shielding attached in step 11. Feed the free end of the wire into the shielding, draw the turns tight, and secure the winding with plastic tape.

14. Cut a piece of brass or copper shim stock as shown in Fig. C13 to a length which will wrap around the bobbin but will not allow the ends of the shim stock to touch each other.

15. Tin the shim stock along the edges.

16. Place the wound bobbin in a vise, wrap the shim stock around it, lining up the free ends of the shim with the slot cut in step 9, and solder the shim to the bobbin ends. Caution. *Do not overheat the winding; the plastic covering melts easily and a short is almost impossible to detect.*

17. Connect an SO-239 coax connector and UG-177/U hood to the shielded primary lead as shown in Fig. C15.

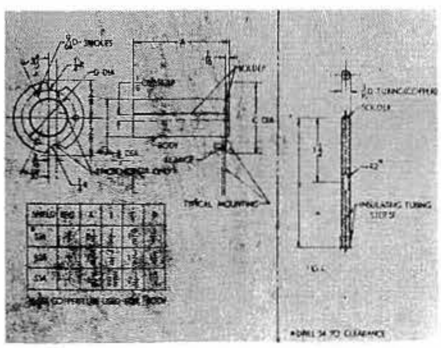
18. Wind one turn of ¼-inch diameter half-hard copper tubing around a 1-inch diameter form. Saw the tubing as shown by "phantom lines" in Fig. C14. Drill as shown in Fig. C14 and clean off all burrs.

19. Locate the 8-inch piece of shielding left over from step 10.

20. Using same technique as in step 11, solder one end of the shielding into the ⅛-inch hole. Clean off all solder splatter and burrs.

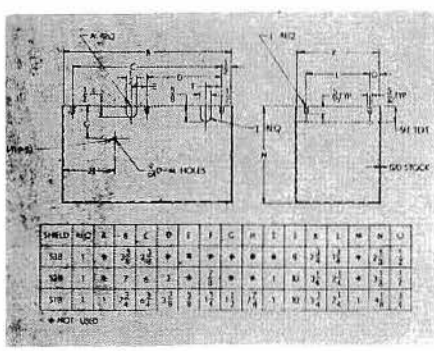
21. Solder one end of another length of No. 26 plastic-covered hookup wire to point A (see Fig. C14) and wind three turns inside the tubing in the direction shown.

22. Feed the free end of the hookup wire through the shielding. Bend the tubing into final shape as shown in Fig. C14. Pull up the three turns snugly, making sure that the plastic coating is undamaged.

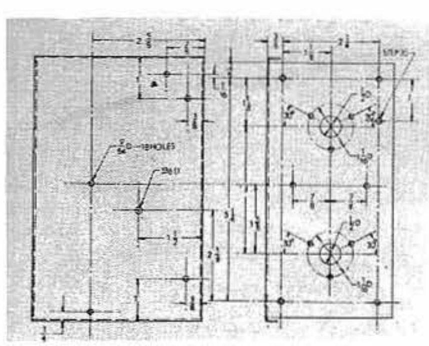


C6—Tube shield, Mat'l .010 Brass

C7 — Shield Assembly S4

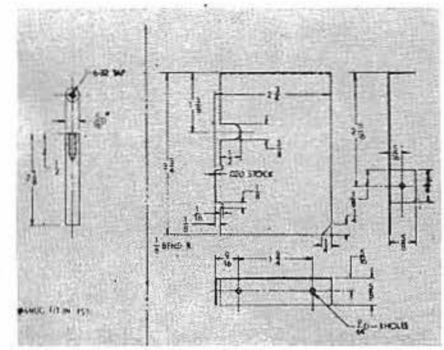


C8—Shield can, Mat'l Aluminum



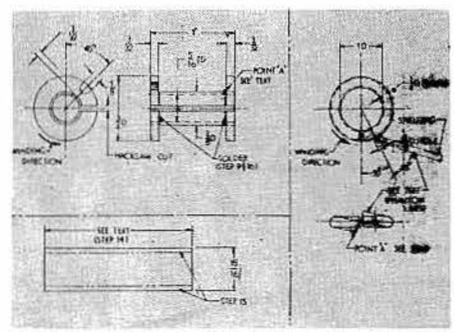
C9—3X4X6 LMB Shield can S5

23. Connect a male phono plug to the free end of the shielded wire as shown in Fig. C15. Length of the wire is critical.



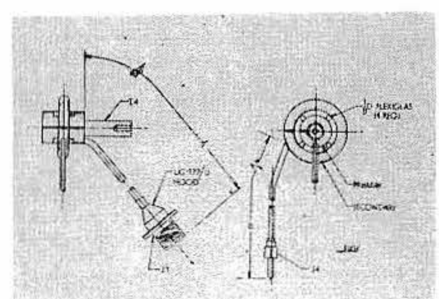
C11 — Insulator 14, Mat'l Plexglas

C10—Shield Partition S5A, Mat'l Aluminum

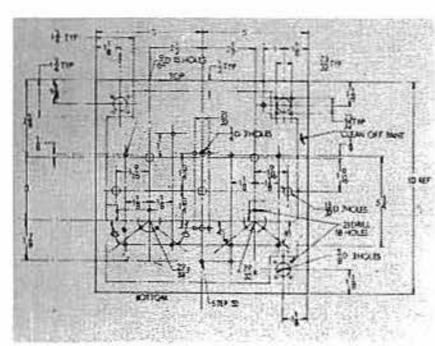


C13—Shield PS1A, Mat'l .005 Brass or Copper
C12 — Primary bobbin PS1, Mat'l Brass or Copper

C14—Shield PS2, Mat'l copper



C15—Transformer assembly



C16—Inside view of panel

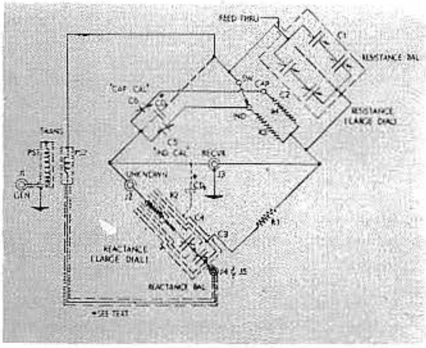


Fig. 1—HF. RF. Bridge Mark III Schematic

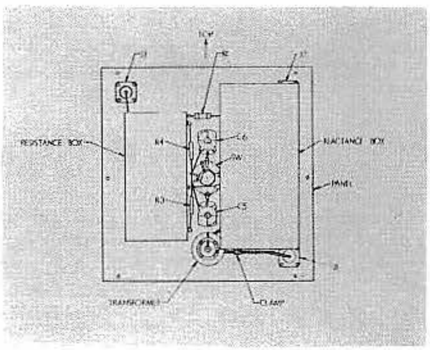


Fig. 2—Inside view

24. Using four pieces of ⅛-inch diameter plexiglas rod as spacers, assemble the primary and secondary shielded windings as shown in Fig. C15. Attach insulator I4 to the transformer by cementing it into the bobbin hole with Duco. Cement both windings to spacers with Duco and allow to dry overnight. This completes the transformer.

25. Remove top and bottom from the 8x10x10 utility box. Remove all paint from flanges; clean to bare metal to provide adequate rf shielding on reassembly.

26. Remove paint from inside of bottom plate for ½ inch in from each edge.

27. Remove paint from inside of top plate as shown in Fig. C16 by "phantom lines."

28. Drill the top plate as shown in Fig. C16.

Note that drawing shows INSIDE surface of plate.

29. Cut shafts of all four variable capacitors to ⅜-inch length. Remove all trimmer capacitors.

30. Tap the threeholes on the face of each capacitor, using a 6-32 tap. Take care not to damage the first stator plate; a bottom tap may be necessary. Attach three type I2 insulators to C1 and C2, using ¼-inch-long 6-32 set screws as shown in Fig. 3. This completes preliminary metalwork.

Actual Wiring

31. Attach C1 and C2 to shield box S5 using six ¼-inch-long 6-32 machine screws. Connect stator lugs of C1 to those of C2 with No. 18 tinned wire, as shown in Fig. 3.

32. Mount two soldering lugs as shown in Fig. 3 and connect remaining stator lugs to them, using No. 18 tinned wire.

33. Press the Erie CF-408 feed-thru into the 0.136-inch diameter hole in S5. Solder a short No. 18 tinned lead from the inside terminal of this insulator to the wire installed in step 31, as shown in Fig. 3.

34. Attach shield partition S5A, using three ¼-inch-long 6-32 machine screws. One of the screws installed in step 32 must be temporarily loosened and removed.

35. Attach four type I3 insulators to shield box S5 as shown in Figs. 3 and C9.

36. Attach three more soldering lugs to S5 as shown in Fig. 3, using ¼-inch-long 6-32 machine screws.

37. Attach four type I3 insulators to shield platform S1, using the 4¼-inch-spaced holes in S1 and 6-32 screws. Attach S1A to S1, using 6-32 screws from the inside of S1. Attach the female phono socket to S1 in the 7/16-inch diameter hole. Attach four type I1 insulators, using ¼-inch-long 6-32 screws. Do not tighten the screw in the hole marked "Hole A" in Fig. C1; this screw will hold a cable clamp later. See Fig. 4 for details of insulator placement.

38. Attach four type I1 insulators to shield platform S2, using the 2⅝-inch-spaced holes in S2 and ¼-inch-long 6-32 screws. Attach S2A to S2. Attach capacitor C3 with 1-¼-inch-long 6-32 screws, using two nuts on each screw as shown in Fig. 4. Mount a soldering lug under one nut as shown. Align the capacitor by adjustment of the mounting screws and nuts.

39. Solder a No. 18 tinned wire to the female phono socket and pass the wire through the corresponding hole in S2. Attach S2 to S1 with ¼-inch-long 6-32 screws going into the type I1 insulators attached to S1 in step 37.

40. Attach C4 to shield platform S3 using ⅝-inch-long 6-32 screws with dual nuts (same as in step 38). Attach S3A to S3.

41. Connect two of the stator lugs of C4 with No. 18 tinned wire as shown in Fig. 4. Slide shield assembly S4 into S3A. Center assembly S4 in S3A, using a piece of ¼-inch-long insulating tubing. Make certain that opposite ends of S4 and S3A are even as shown in Fig. 4, and cement tubing in place with Duco. Solder the shorted end of resistor R2 (which is in S4) to the wire connecting stator lugs of C4.

42. Attach shield platform S3 to S2, using ¼-inch-long 6-32 screws going into the type I1 insulators installed on S2 in step 38.

43. Place a ¼-inch-long 6-32 screw in the flange of S3 as shown in Fig. 4, with a soldering lug. Connect this lug to the stator lug of C3 with No. 18 tinned wire. Using ¼-inch-long 6-32 screws, mount a soldering lug in Hole B (see Fig. C1) of S1 and another in S2 as shown in Fig. C2. These lugs are mounted in a direction opposite to that of the platform flanges.

44. Attach the "unknown" ground lug to the panel next to the "unknown" coax connector hole, as shown in Fig. C16. Attach the "receiver" coax connector to the panel, from the inside. Attach the "IND-CAP" switch to the center of the panel, using an extra nut to position the switch as far as possible from the panel. Orient the switch as shown in Fig. 5. Place a soldering lug under each nut. Mount C5 and C6, using ⅜-inch spacers between the capacitor frames and the panel. Connect the

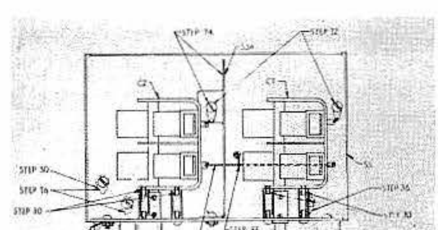


Fig. 3—Resistance box—Inboard view

rotors of C5 and C6 to the lugs of the switch with No. 18 tinned wire as shown in Fig. 5.
45. Solder a 2½-inch length of No. 18 tinned wire to the "COMMON" terminal of the switch. Connect the stators of C5 and C6 to the remaining switch terminals, as well as resistors R3 and R4. Complete connections are shown in Fig. 5.
46. Attach the "unknown" coax connector to

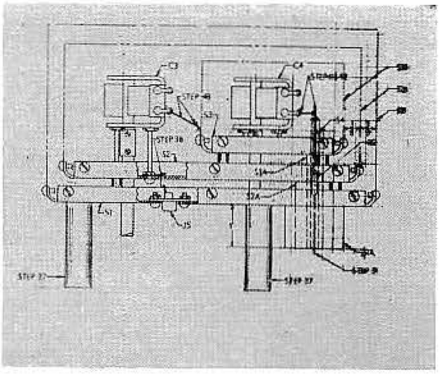


Fig. 4—Reactance Assembly—Inboard view

the panel, placing a soldering lug under one mounting screw. Connect the "unknown" ground lug to this soldering lug to provide a good bond.
47. Mount panel bearings for capacitors C2 and C4. Mount the special panel bearings furnished with the Johnson Vernier Dial assemblies in place. Attach the two large dials to dummy shafts and mount the dial indicator in the position you prefer. Remove the large dials and dummy shafts after placing the dial indicators.

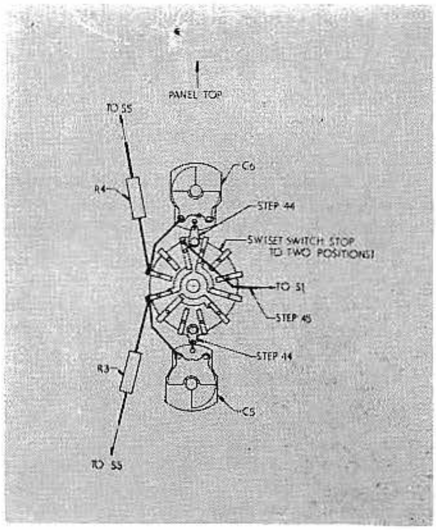
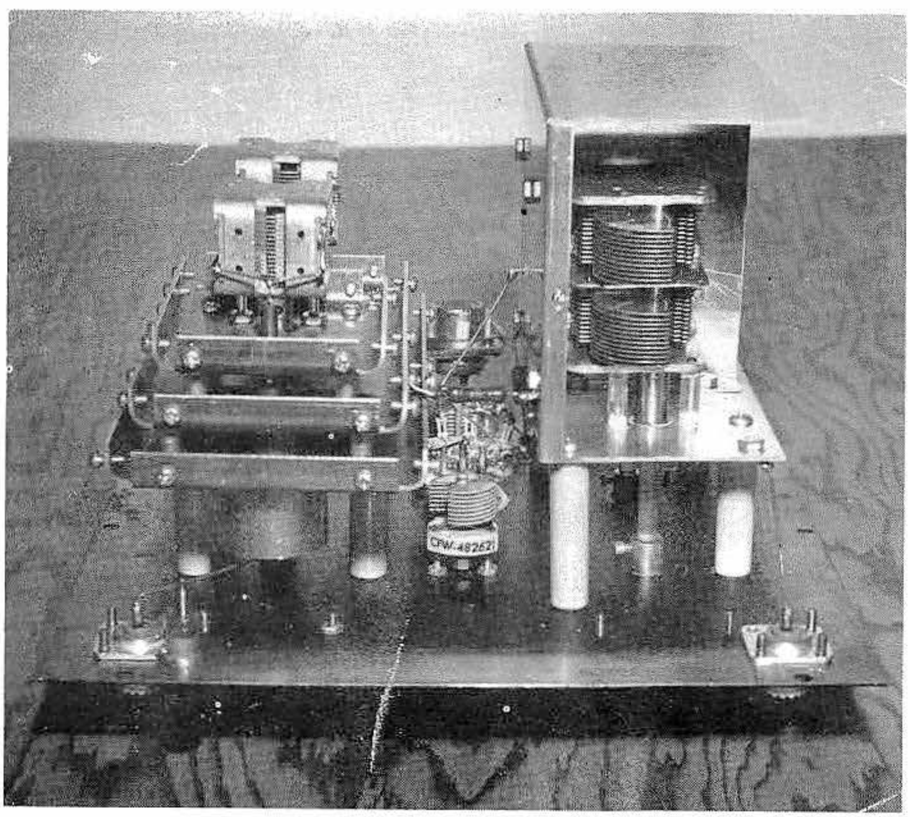


Fig. 5—Switch Assembly

48. Mount S5 at the left side of the panel (as shown in Fig. C16) and mount the assembly of S1, S2, and S3 at the right side. See Fig. 2.
49. Attach shaft couplers to the four capacitors. Cut the plexiglas shafts to length and mount them in place. Attach the large vernier dials. Set the dial of C2 so that it reads "0" at minimum capacity. Set the dial at C4 so that it reads "100" at maximum capacity. Mount the two Calrad dials on the panel, setting them so that they both read "0" at maximum capacity. Attach the knob to the "IND-CAP" switch.
50. Connect resistor R1 (270-ohm deposited-



carbon) from the soldering lug on S2 to the lug in line on S5. Connect R3 (220 ohms) and R4 (100 ohms) to the soldering lugs on S5 which were installed in step 36. R3 will be the resistor nearest the bottom of the panel.
51. Connect a No. 18 tinned-wire lead from the "detector" coax connector to the lug on S5. Connect a No. 12 (note different wire size) lead from the "unknown" connector to the free end of R2. *Make sure that R2 is not shorted to any shield.*
52. Attach the transformer, completed in step 24, to the bottom of the panel as shown in Fig. 2. Attach the coax connector connected to the transformer to the panel in the "signal generator" hole. In the hole between the transformer and the connector, mount a cable clamp to hold the shielded primary lead. Secure the

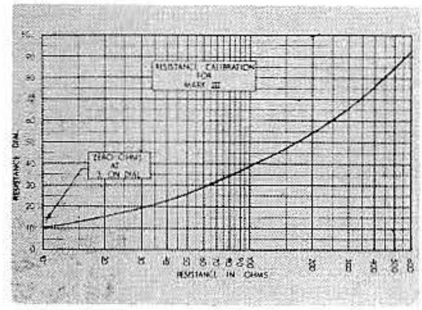


Fig. 6

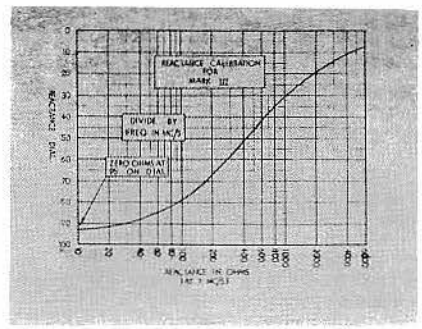


Fig. 7

shielded secondary lead with another clamp held by the loose screw installed in step 37.
53. Mount a soldering lug to S1B with a ¼-inch-long 6-32 screw, placing the lug in the direction of the box opening.
54. Place ¼-inch-long 6-32 screws in all remaining tapped holes in S1, S2, and S3. Starting with S3, place all shield boxes in place and secure screws. Connect a No. 18 tinned lead from the soldering lug installed in step 53 to the Erie feed-thru on S5. Set C5 and C6 to mid-capacity.
55. Attach four rubber feet to the bottom plate of the case and four more to the bottom side of the utility cabinet. Restore the front plate in place and secure with the sheet-metal screws provided. This completes construction of the bridge. After calibration, it will be ready for use.

Calibration and Use

Since the Mark III is a null-type instrument (adapted from the Schering bridge circuit) it can only be used with a signal generator and a detector. Both must be shielded; however, a Heath SG-8 will do nicely as the signal generator and any decent communications receiver will serve as the detector. For best results, it

should be calibrated with the signal generator and receiver with which it will be used.

56. Connect the bridge to the signal generator and the receiver, using coax cable from the panel connectors to each.

57. Set both the signal generator and the receiver to 2 mc.

58. Short the "unknown" terminal and ground terminal using a banana plug in the connector or a coaxial short made by soldering the pin of a PL-259 connector to the shell through a copper disc.

59. Set the "IND-CAP" switch to "CAP."

60. Set the "Reactance" dial to 15.

61. Set the "Resistance" dial to 5.

62. Tune the signal generator, only, for maximum signal in the receiver.

63. Using the two small "balance" dials, reduce the signal in the receiver to the lowest level possible. This is the "null" or "balance" condition. The dials will interact, and multiple adjustment will be necessary. However, all receiver and signal generator adjustments must be left alone during this step.

64. Replace the short across the "unknown" connector with the 620-ohm deposited-carbon "test" resistor.

65. Using only the large "resistance" and "reactance" dials, null out the signal once more. Record the final reading of the "resistance" dial. If this reading is 95, you are extremely lucky and the first half of the calibration is complete. If not, proceed with step 66.

66. If the "resistance" dial reading is less than 95, increase the capacity of C6 slightly and repeat steps 60 through 65. If the reading is larger than 95, decrease the setting of C6 and repeat steps 60 through 65. Continue this process until the reading comes out at 95.

67. When capacitive calibration is complete, set the "IND-CAP" switch to "IND," and the "reactance" dial to 30.

68. Repeat steps 60 through 65; if the final reading of the "resistance" dial is other than 95, proceed with step 69.

69. If the reading is less than 95, increase the capacity of C5 slightly and repeat steps 60 through 65. If the reading is larger than 95, decrease the setting of C5 and repeat. Continue until the reading is 95. This completes calibration, and the curves shown here can be used for readings.

Using the Mark III

To use the Mark III, set the instrument up as described in step 56 of the calibration procedure. Set the signal generator to the desired frequency and short out the "unknown" terminal of the bridge as described in step 58.

If you're measuring an inductive impedance, set the "IND-CAP" switch to "IND," the reactance dial to 95, and the resistance dial to 5. Null the signal with the small balance dials.

Now remove the short and connect the unknown. Rebalance the bridge using the large dials, note the readings, and convert the readings to ohms by use of the calibration curves.

These initial values must be corrected. The reactance value is corrected by dividing the value read from the curve by the frequency (in mc) at which the reading was taken. The resistance value is corrected by obtaining the correction factor due to frequency from Fig. 8 and multiplying the reading by this factor.

If you're measuring a capacitive impedance, set the switch to "CAP." Then estimate the reactance of the unknown and set the large reactance dial to a value just larger. Set the resistance dial to 5 and short out the "unknown" connector. Null the signal with the short and again with the unknown, the same as for an inductive impedance.

Correct the resistance reading in the same manner as for an inductive impedance. However, the reactance reading is corrected differently: Subtract the value taken from the calibration curve from the value originally set on the reactance dial. Now divide this remainder by the frequency (in mc) at which the reading was taken. The result is the true value of capacitive reactance.

A few minutes' practice will make operation of the Mark III far more simple than the detailed directions would indicate; in practice, you can make a reading in less time than it takes to read these paragraphs.

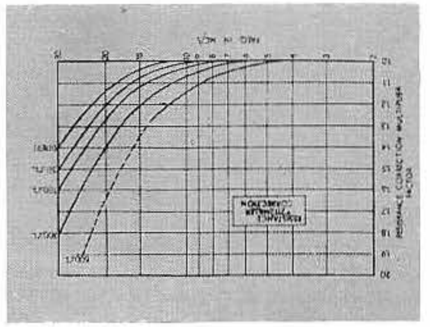


Fig. 8

Parts Substitutions and Design Changes

Since few hams are content to build a "Chinese copy" of someone else's design, a few words on the effect of changes are necessary.

Naturally, the Mark III doesn't represent the only possible—or even necessarily the best—way in which such a bridge can be built. Any part, or all, may be changed. However, any such change will invalidate the calibration curves, and is not recommended unless the builder has access to laboratory equipment.

Even then, before making any substitutions, these three design articles should be read and fully understood:

"A Radio-Frequency Bridge for Impedance Measurements From 4000 KC/S to 60 MC/S," D. B. Sinclair, Proceedings of the I.R.E., November, 1940, pages 497-502.

"A High Frequency Model of The Precision Condenser," D. B. Sinclair, General Radio Experimenter, October-November, 1938, pages 1-7.

"The Effect of Stray Capacitances to Ground in Substitution Measurements," M. Reed, Wireless Engineering, May, 1936, page 284 ff.

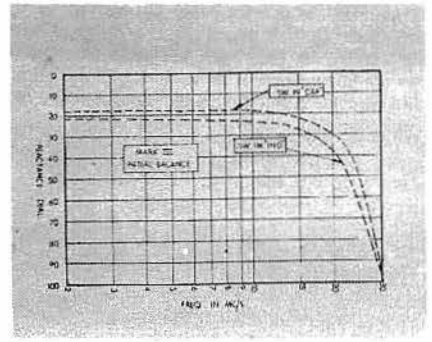


Fig. 9

Parts List

Quan.	Item	Description	Cat. No.
1 ea.	C1, C2	[illegible], 10-365 mmf/sect.	2112
1 ea.	C3, C4	Miller, 10-365 mmf	2111
1 ea.	C5, C6	50 mmf air padder (good quality)	APC-50
1 ea.	J1, J2, J3	SO-239 Panel coax connector	
1	J4	Phono plug	
1	J5	Phono socket	
1	R1	Aerovox 1% 1/2W 270 ohm "Carbofilm"	Type-CP
1	R2	330 ohm 5% 1/2W Carbon Resistor	
1	R3	220 ohm 5% 1W Carbon Resistor	
1	R4	100 ohm 5% 1W Carbon Resistor	
1	Test	Aerovox 1% 1/2W 620 ohm "Carbofilm"	Type-CP
1	SW	Centralab 3p; 1 Sect; 2-3 Position (reset stop to two positions only)	2506
*2	Dials	E. F. Johnson Vernier (0-100 CW)	116-285-1
2	Brgs	E. F. Johnson Panel Bearings	115-255
4	Cplrs	Metal ¼ shaft couplers	
3	Rod	¼ inch diameter plastic rod x 12"	
1	Rod	⅛ inch diameter plastic rod x 6"	
2	Rod	⅜ inch diameter plastic rod x 12"	
2	Dials	"Calrad" 1-13/32 inch Vernier Dial	VD-36
1	BP	Binding Post (ground lug)	
1	Case	Bud carrying case 10"x10"x8"	CC-1100
1	Box	LMB box (plain) 3" x 4" x 6"	
1	Hood	UG 177/U coaxial cable hood	
1	Insul.	Erie feed-thru insulator	CF-408
1	Short	PL-259 coaxial male connector	
2	Clamps	Walsco clamp for ⅛ to 3/16 cable	7502-N

Of the above list the critical parts are:
C1, C2, C3, C4, J2, R1, Test resistor, Case, LMB box, UG 177/U, Erie feed-thru.

* This author hand engraved these dials per Figs. 6 and 7.

MEASURE RF IMPEDANCE WITH YOUR SWR BRIDGE

Warren McDowell W2AOO

So far, the great majority of antenna impedance bridges that we have found in construction articles are devices that function only with a low power rf source. The run-of-the-mill impedance bridge is designed to operate with a grid dipper as the source of rf excitation. Operation with tube type dippers is generally intended as the transistor dippers produce an rf level that is too low for excitation of this bridge type.

The conventional antenna bridge cannot be left in the transmission line continually as excessive rf energy would soon destroy the device. This means that each time measurement of antenna impedance is desired, the transmission line must be opened and the bridge inserted and grid dip excitation applied. Grid dippers are not necessarily the most accurate rf source for a specific frequency in an amateur band . . . therefore the station receiver must monitor the dipper output for any bridge accuracy. A low power bridge will not often present the true operating impedance of the antenna . . . especially antennas with parasitic elements. A bridge that operates under full transmitter power will present a much more accurate picture of your antenna system at a specific frequency.

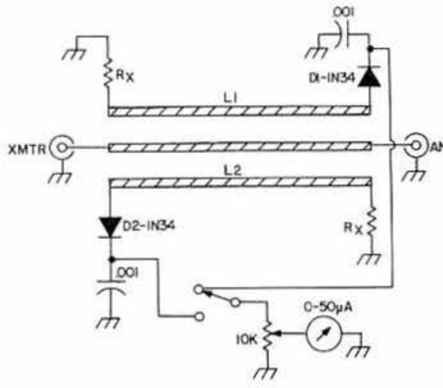


Fig. 1. Conventional swr bridge.

Inspiration for the "In Line" full power bridge came from information concerning the standard swr bridge. Just about every amateur has in his possession some sort of swr bridge and the great majority are of the type illustrated in Fig. 1. This bridge consists of a section of transmission line near which are placed two inductors. These inductors are actually two bridges along with their associated diodes and resistors. One of the bridges reads forward power and the other reflected power. The resistors (Rx) at the end of the inductors L1 and L2 are critical for accurate bridge null (balance) and therefore must be the proper value for the specific transmission line used. For the average swr bridge the value for Rx is 100Ω for 75Ω line and 150Ω for 50Ω transmission line. Considering that resistor Rx is critical for the impedance of the line in use, varying the value of Rx and devising a system of calibration for Rx would enable us to determine the impedance of a line when a null is achieved on the bridge meter.

The "reflected" inductor which is L1 in Fig. 1 is the portion of the bridge circuit we are interested in for impedance measurements. The value of Rx and the transmission line must balance the bridge for a null to be realized. Any variation from the above parameters will mean changing the value of Rx so that the bridge again balances at a new impedance value.

By experimenting with various values of resistance at Rx, it was determined that a 1000Ω potentiometer represents a fair value. The 1000Ω potentiometer is inserted in place of Rx on inductor L1 (see Fig. 2). This is the inductor with the diode pickup located toward the load or antenna end of the swr bridge.

Make sure that all leads to the 1000Ω potentiometer are short and that the metal case (shell) of the potentiometer is well grounded. Excessive lead length or inductance will create inaccuracy of the device. The position of the potentiometer will be determined by the physical layout of your particular swr bridge. It must be set at a point where the shaft can be extended through the front panel of your swr bridge. Allowance must also be made for a dial or other indicating device which can be calibrated in ohms (impedance) on the front panel. It might even be desirable to mount your entire present bridge in another larger case so that all functions can be accommodated.

Calibration of this in-line bridge was the major problem. An ordinary grid dip meter will not provide sufficient excitation for readings. With full power applied, especially a kilowatt, it becomes difficult to find resistive dummy loads of various values to calibrate the bridge. Even with 100W of rf, proper resistive load values are not common.

The solution to the calibration problem came to us in the form of an (ouch!) CB transmitter. A CB transmitter is fortunate if it is able to put out 3W of rf and at the same time is well within the frequency range of an swr bridge. The most important fact is that a CB transmitter will provide adequate excitation for calibration of the bridge with ordinary 5W 5% carbon (garden variety) resistors. For calibration, a good assortment of these resistors is necessary. Use values such as 5, 27, 47, 75, 100, 150, 220 and 470Ω. Intermediate values can be then interpolated on your scale. The calibration procedure is simple . . . first borrow your neighbor's CB, then attach the 5W resistors across the antenna coax connector of the bridge and excitation of the CB transmitter is applied to the remaining connector on the bridge. The bridge sensitivity should be set for a middle scale reading of the meter and the 1000Ω potentiometer is varied until you reach a null on the meter. Mark the value of the calibration resistors on the potentiometer scale (dial). Do this for all of the available resistors and your bridge will be in fair calibration.

At this point we should mention that this system does not measure reactive components in the antenna system. If your antenna is reactive, either inductive or capacitive, the meter will present a shallow, poorly defined null at the operating frequency. A sharp, well defined null will indicate a purely resistive impedance.

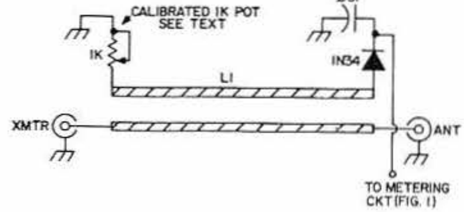


Fig. 2. The modified bridge leads to 1K pot should be as short as possible and shell (case) of pot grounded.

When using the bridge in its former function as an swr bridge, set the resistance dial to the value of your transmission line. When measuring impedance, vary the dial for maximum dip on the meter and read the resistance (impedance) directly.

As a final point, it is wise to insert the swr/impedance bridge at a half-wave or an even multiple of a half-wavelength from your antenna. At half-wave points from the antenna, the antenna impedance is repeated. This will enable your measurements to be much more accurate. When determing half-wavelength points, take into consideration the velocity factor of your particular coax.

USE YOUR GDO AND Z METER

Denys Fredrickson WØBMW

The GDO is one of the most versatile pieces of test equipment available. Yet there are many hams who don't know how or when to use one. The writer will try to describe and explain some of its various functions.

The GDO is basically a variable high frequency oscillator with a frequency range of approximately 550 kc to 250 Mc. It may also be used as a diode detector or wave meter. The GDO gets its name from the fact that a meter measures the grid current and when the oscillator circuit is coupled to a resonant circuit a reduction in grid current is obtained. This is called the grid dip. However, when it is used as a wavemeter and coupled to an rf source, an increase in current is obtained at resonance.

The GDO and impedance meter can be used to accomplish the following:

1. Determine the resonant frequency of tuned circuits, including antennas.
2. Determine the impedance of circuits, receiver inputs and antennas.
3. Determine the length of half-wavelength or quarter-wavelength transmission or tuning stub lines.
4. Determine the "Q" of a circuit or component with the aid of a VTVM.
5. Determine the resonant frequency of individual coils, capacitors or crystals that are within the range of the GDO.
6. Determine the rf frequency of energized circuits.
7. Monitor a radiated rf signal with the aid of headphones.
8. Neutralize rf stages.
9. Locate parasitic oscillations.
10. To align receivers and television sets.
11. Determine where BCI and TVI is entering the radio or television receivers.
12. Determine unknown inductance.
13. Determine unknown capacitance.

Now if you will step into the lab we will try to demonstrate how these instruments can be put through their paces. Let's begin with

the simple functions and then gradually creep up to those which are more complex so they don't scare us before we get started.

An oscillator-detector

Simply plug in a pair of headphones (if GDO has facilities for them) and "zero-beat" with the radiating signal. This then will be the frequency of the radiating signal.

Crystal frequencies

Connect a one turn loop of wire across the crystal and couple the GDO close enough to get a dip of the meter when resonance is obtained. It is always wise to check lower frequencies to be sure it is the fundamental frequency that is being indicated.

Frequency determination

Generally the GDO has a switch which is used to remove the plate voltage from the tube. The tube will then serve the function of a diode and the meter as a diode load. When a peak deflection of the meter is obtained this will indicate the frequency of the radiating signal.

Resonance of an RF choke

When an rf choke is used as a parallel or shunt fed circuit, it must be free of self resonance over the operating frequency range of that circuit or it may burn up. The popular pi tank circuit is an example. Place a short circuit across the choke and then determine its self resonant frequency by coupling the GDO close enough to indicate a dip on the meter when the resonant frequency is obtained.

Neutralization

Apply plate power to the exciter stages and filament power only to the stage being neutralized. Use GDO as a wavemeter and couple close to the tank coil in the stage being neutralized. Vary the frequency of the GDO until maximum reading is obtained and then adjust the neutralization for minimum GDO meter reading. The circuit being neutralized may have to be retuned and the above procedure repeated with a closer coupling of the GDO to the Tank coil.

IF alignment

Tune the GDO to the desired frequency and couple it close to the if coil to be aligned. Adjust the if coil until a dip is observed on the meter. The if coil will then be tuned to the desired frequency.

Inductance and capacitance checking

To determine the value of an unknown capacitor, connect it across a known inductance and use the GDO to find the resonant frequency of the circuit. With these known values a reactance chart will give the value of the capacitor. Some GDO's supply a chart which corresponds to the coils supplied with the GDO as the known inductances. To determine the value of an unknown inductance, connect a known capacitance across the coil and use the GDO to find the resonant frequency. Again, the reactance chart may be used or the following formula (which may be used for either inductance or capacitance) for resonant circuits:

$$L = \frac{1}{39.48\ (f^2)\ C} \quad \text{or} \quad C = \frac{1}{39.48\ (f^2)\ L}$$

Where f = cycles per second
L = inductance in henries
C = capacitance in farads

The inductance of an air core coil can be estimated by the following formula:

$$L = \frac{(rN)^2}{9r \neq 10w}$$

Where L = inductance in microhenries
N = number of turns
r = radius of coil in inches
w = length of coil in inches

Q measurements

Connect a condenser across the coil so the tank circuit resonates at the desired frequency. Connect a VTVM across the tuned circuit and tune the GDO until maximum reading is obtained on the VTVM. The GDO coupling may be changed until a convenient value is obtained on the VTVM and then it must not be moved during the remainder of the test. Note the resonant frequency f_e then detune the GDO to a lower frequency until the VTVM reads 70.7 percent of its original or peak value and call this frequency f_1. Now detune the GDO to a higher frequency until the VTVM again reads 70.7 percent of its original or peak value and call this frequency f_2. The Q is then calculated by using the following formula:

$$Q = \frac{f_e}{f_3}$$

Where f_e = is the center of resonant frequency
f_3 = the difference between f_1 and f_2

Parasitic oscillations

By using a pair of headphones with the GDO, the parasitic oscillation frequency may be determined. Turn the power off of the stage being checked and then use GDO to find the circuit which resonates at the parasitic frequency by moving the GDO slowly around the wiring. When a "dip" is observed, moisten the finger and touch an ungrounded point of the circuit. If a change in the dip is observed, it indicates that it is the portion of the circuit that would be a likely suspect.

BCI and TVI locator

Most of the BCI and TVI problems can only be resolved at the receiver, either by installation of filters, resistors or condensers or a combination of all three. The problem is—where is the rf entering the receiver? Use the GDO tuned to the frequency which produces the greatest amount of interference. Probe around with the GDO until the most sensitive spot is located, which is indicated by watching or listening to the receiver interference. After the point of entry is determined then the appropriate corrective action can be accomplished.

Antenna measurements

Space does not permit to discuss all types of antennas and adjustments so only a few will be mentioned to give some idea on the use of the instruments. At this point it should be mentioned that inductive type coupling should be used between the GDO and antenna when checking near the current maximum point and capacitive coupling when checking near the voltage-maximum point.

The beam antenna has gained tremendous popularity in recent years plus many headaches for those striving to obtain the maximum effectiveness. Most of the headaches can virtually be eliminated by using the GDO and Impedance meter (Z-meter). Let's take a look at a 3 element yagi and see what has to be done to obtain a good adjustment. The element lengths must be physically adjusted or electrically loaded to obtain resonance at the desired frequencies and the feed point impedance must match the impedance of the transmission line. These two points are not the only considerations for beam adjustment but they are the most important factors. The GDO can be inductively coupled to each element and the elements adjusted until each one is resonant at the desired frequencies. It is best to make the measurements while the antenna is in operating position. This is very difficult to do in many cases but let's assume you can. After the elements have been adjusted, the feed point must be adjusted to match the line. The Z-meter and GDO will be used to accomplish this adjustment. The Z-meter is basically a resistance type bridge with a calibrated potentiometer as one of the bridge arms. Connect the Z-meter directly to the antenna feed point. Couple the GDO to the Z-meter inductively thru a couple loops of wire connected to the other terminals of the Z-meter. Tune the GDO to the resonant frequency of the beam and adjust the Z-meter to the dip or null. If the impedance indicated by the Z-meter is not the same as the transmission line then readjust the matching network and redip the Z-meter until the impedances are equal.

Now—if you can't adjust the antenna in the operational position you still can determine the resonant frequency and the impedance by standing on the good old Terra-Firma. The procedure is a little more involved but effective. First—we must have a means of electrically connecting the instruments to the antenna. This is best accomplished by a transmission line a half-wave or a multiple of a half-wave in length. Determine the height of the antenna above ground and calculate how many half-wave lengths of line will be required by using the following formula for a half-wave length of line:

$$L = \frac{(492)\ (K)}{f}$$

Where L = feet
f = megacycles
K = propagation constant
(RG/8 is .66)

This is an approximate length so be sure and cut it extra long because now we will find the exact physical length. Why an exact physical length? A halfwave length of transmission line will reflect the resistance placed across the output at the input end of the line, i.e. if a 50 ohm non-reactive resistor is placed across one end of a half wave or multiple length thereof, the GDO and Z-meter will indicate 50 ohms at the other end of the line. Cut the line somewhat longer than calculated above, short one end and connect the Z-meter to the other end of the line. NOTE: Keep twin lead off the ground and away from metal objects. Set the Z-meter to zero impedance and couple the GDO inductively to the Z-meter. Adjust GDO frequency until the fundamental frequency causes the Z-meter to dip or indicate a null. The frequency indicated should be lower than the desired frequency. Simply cut a few inches of cable off, short the end again and readjust the GDO. Repeat this procedure until the desired frequency (which should be the same as the resonant frequency of the antenna) is obtained. You will then have an electrically halfwave length of line or a multiple thereof.

Coax or twin-lead may be used for the halfwave length line when checking the impedance of the antenna. Connect the line to the antenna, hoist the antenna up to its operating position and adjust both the Z-meter and GDO for the null indication. If the antenna is not resonant at the desired frequency, the driven element should be readjusted a measured amount and then note the frequency change. This will give you an idea how much the resonant frequency changes with a corresponding element change. Now adjust the matching network to the desired impedance. This will be accomplished when the Z-meter dips at the desired impedance with the GDO set at the resonant frequency of the Antenna.

What would you do if your 100 foot coax cable developed a short someplace along the line? Replacing the whole line would be too expensive. Simply connect the Z-meter to one end of the line, adjust the Z-meter for zero impedance and then adjust the GDO for lowest frequency which will produce a null on the Z-meter. Use this frequency in the formula given for a halfwave length line and carefully calculate the length which will be the distance from the input end to the short.

A quarter wave length tuning stub can also be determined by using the procedures just outlined for the halfwave length line except a quarter wave line reflects a short at the input when the output end is electrically open. Now that we have mentioned the quarter wave length line, some may be wondering just what useful purpose does it serve. The quarter wave tuning stub (as it is sometimes called) may be used for antenna matching, TVI elimination or matching two units which have different impedances. The quarter wave matching stub can be used as a matching device on antennas which is explained in most antenna handbooks. It may also be used to eliminate an interfering frequency from entering the TV. This is accomplished by connecting a quarter wave stub to the TV antenna terminals which is a quarter wave in length at the interfering frequency.

Another use for the quarter wavelength matching stub is to permit maximum signal transfer between the source and a load which have different impedances. If the signal source impedance was 100 ohms and the load impedance was 52 ohms, a 72 ohm quarter wavelength of line would give a good impedance match. Hold it just a minute, how in the world did we come up with that 72 ohm business? Simple—another formula will give us this information.

$$Z_o = \sqrt{Z_s\ Z_a}$$

where Z_o = Impedance of quarterwave matching stub
Z_s = Impedance of the source
Z_a = Impedance of the load

Very little has been said concerning the various methods of GDO coupling. Actually—only two types of coupling are used; inductive and capacitive. Capacitive type coupling may be used on shielded coax cable, the ends of antenna elements and generally where the voltage maximum exists. To obtain the greatest accuracy, the GDO should be loosely coupled. Parallel coupling to inductors can be used to obtain maximum coupling.

Chapter III

Measuring RF Power Output

MEASURING RF OUTPUT

Paul Schuett WA6CPP

So your new Bandjammer 5000-Q is rated at 752W peak power. Big deal. How much of this is getting out where it counts?

It's easy to find out by inserting an rf ammeter in series with the line. A more exact reading would be to have the rf ammeter at the antenna input terminals, but that might be impractical when it comes to reading the meter (although you could put a diode there and a remote-reading meter in the shack).

Recently I found an rf ammeter at one of the mail-order surplus houses for $2.95. I installed this in a little cabinet, put two coax connectors on the back (in and out) and now can read rf current in the line, into the dummy antenna, or wherever it is going.

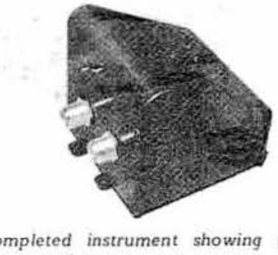
Remember the formula $P=I^2R$? Square the reading on the meter, multiply by the impedance of the line you're using, and you have the power past that point. At the antenna, you could determine the antenna resistance and take the current reading at that point.

For those who have difficulty with mental computations and can't find a pencil, the following chart fives the computed power levels present in matched 50 and 70 Ohm coaxial lines for various levels of rf current:

RF Current	Power Output in Watts	
Amperes	50 Ohm Line	70 Ohm Line
0.5	12.5	17.5
1.0	50	70
2.0	200	280
3.0	450	630
4.0	800	1120
5.0	1250	1750

When tuning up the rig, place the ammeter on the antenna side of any tuning or matching devices and tune for maximum current.

Inside wiring is extremely simple. Note ground wire installed to insure continuity of the shield circuit.



The completed instrument showing the coax connectors on the rear.

It's amazing to learn how much (or how little) current these rigs produce. For instance, my Swan 250-C puts 1.35A into a 50Ω line. My friend's SB101 from Heathkit put out 0.7A until we worked on the antenna – then it put out about 1.25A. My Heathkit SB401 puts anywhere from 2 to 0.6A into a 50Ω Cantenna, depending on what band it's on.

Commercial stations determine their power by the antenna current. Knowing the antenna resistance at the operating frequency, they multiply that by the current squared. If the antenna resistance is 62½Ω, 4A rf would be 1 kW into the antenna. 126.48A would be 1 MW.

Remember the ammeter does insert a little reactance in the line (I never leave it in all the time), and the calibration changes with frequency, although you can tell what side of the ballpark you are on. An rf ammeter in the shack makes a nice piece of test equipment.

LIGHT BULBS AS RF INDICATORS

John Houser WB2GQY

The major appeal to the amateur – as well as some commercial applications – of light bulbs as rf power indicators is low cost. To this must be added the universal availability of bulbs and screwbase sockets for pennies.

As low cost is of primary interest to well over 50% of those interested in any project, and as I have always had an insatiable desire to find out the why's and wherefore's of standard light bulbs as rf power indicators, I decided it might be the opportune time to do a resarch project and determine once and for all just which bulbs might be suitable and which might not be, and also to determine whether light bulbs would make *good* rf power indicators, or poor, and to find out what precautions might have to be taken if one decided he was going to take this low-cost path of determining his transmitter output power rather than go for a more expensive power output meter.

Also, power output meters in the higher wattage ranges become quite expensive compared to the $2 to $5 which might be expended in a light bulb indicator. In general, porcelain screw bases are available for from 12¢ to 25¢ each, and bulbs from 15¢ to 65¢ each, and not more than four of each are necessary for up to 3 KW power indication.

Table 1 lists most of the common types of electric light bulbs readily available. One look at this table immediately reveals why such light bulbs might not be such good rf power indicators as some folks may have thought they were in the past. It also reveals that some very special precautions have to be taken in using them, or the user may find he has overloaded his transmitter and burned up a few components which might be expensive to replace.

Table 1

Variation in Resistance, Cold to Hot State, Common Variety of Electric Light Bulbs.

Bulb Rating Watts At 115V	Cold Filament Resistance	Hot Filament Resistance	Ratio Cold to Hot Filament Res. (Approx.)
7.5	166	1750	1 to 10
25	40	529	1 to 13
40	27	331	1 to 12
60	20	219	1 to 11
100	9	132	1 to 15
150	6	83	1 to 14
200	4.5	65	1 to 14
250	3.5	53	1 to 15
500	2	26	1 to 13
750	1+	17.7	1 to 15

Table 2

Possible Configurations for Various Power Outputs at Various Impedance Terminations

A. – Nominal 70 to 73Ω Impedance Loads:		
175W Load:	3–60W bulbs in parallel	(73Ω)
	OR	
	7–25W bulbs in parallel	(70Ω)
3,000W Load:	4–750W bulbs in series	(71Ω)
B.) Nominal 50 to 55Ω Impedance Loads:		
250W Load:	4–60W bulbs in parallel	(54.9Ω)
500W Load:	2–150W bulbs in series, both paralleled by 1–150W bulb	(55Ω)
1,000W Load:	2–500W bulbs in series	(53.6Ω)
2,250W load:	3–750W bulbs in series	(53.1Ω)

The extremely high ratio of cold to hot filament resistance in all types of these bulbs immediately struck me as being the most undesirable factor in using them.

It is very easy to see, for instance, that if one wished to use a 250W bulb for indication on a 250W transmitter, and he computed the resistance at 250W to be 53Ω, (which it is, but only when *hot*), he would assume he had just about a perfectly matched indicator to plug in in place of his 52.5Ω feed line.

However, from this table, it is apparent that this 53Ω resistance is attained *only* at full brilliance and wattage, and the actual cold resistance is only 3.5Ω. In other words, if the bulb were connected to the antenna terminals of the transmitter, and the transmitter keyed full power, the transmitter would be looking into *not* 53Ω, but 3.5Ω, which is a lot of difference, and an extremely low value for any pi network to match.

For a few seconds, until the filament attained full brilliance, the transmitter would be subjected to a terrific overload, due to this impedance mismatch.

Therefore the first precaution which might be emphasized in using light bulbs would be *not* to key the transmitter at full power with a cold bulb, but to gradually bring the power from some lower value to full power as the bulb attains full brightness (and hot, matching resistance).

Not until I got into this project did I realize the very high ratio of resistance of these filaments from the cold to hot state; I don't suppose very many people do. It also brings to mind how the house electric meter must jump every time a bulb is snapped on in the house. This is not an ad for those light dimmers being sold at all the electrical stores, but it sure brings to mind that power bills could be cut appreciably through their use, i.e., bringing the bulb gradually to full brilliance instead of just snapping on a switch.

Getting back to the bulbs, Table 2 gives in various configurations series, and/or parallel combinations which would be most likely to give the amateur a load for a particular transmitter power output, in nominal impedances near 52 and 72Ω. If the configuration mentions 200W, this does not mean that it would be suitable for indicating the output of a 100W output transmitter, because at half brightness, the resistance offered by the bulb is not identical to that at full brightness.

While a differance of an ohm or two would not be serious, nor would a difference of as much as five, or even ten watts, at high power levels, at low power levels less than 100W, for instance, such differences would be seen to become increasingly serious from the matched impedance standpoint. The configurations given match quite a variety of standard line impedances and a wide range of power outputs. Matches can be obtained for RG-8, 11, 17, 13, 58 and 59 type cable.[1]

One may not realize without measurement that the lead length of the filament support wires alone inside the 25–150W bulbs is very close to 18 cm. Even though they are coiled on a 2 to 1 ratio, the filament is inductive in every sense of the word. At higher frequencies, the filament support wires would appear inductive, and to these factors must be added the parallel capacity of the screwbase shell and the central base contact wafer. Even though such capacity is small, it would become significant at most amateur frequencies above the 30 MHz range. Though the 22 cm total wire path would perhaps indicate a bulb could be used up to 300 MHz, such is not at all the case.

It is easy to see that the sometimes suggested trick of using a capacitor in series with a light bulb as a load should be approached with caution, for it would be very easy indeed to run into a series resonant circuit which might result in damage to the transmitter to which such circuit were connected.

In the course of my preparation of this article, I discussed the ramifications with a number of interested hams. Some of them suggested I extend the research to include the use of the smaller types of indicator (pilot) bulbs as loads for testing out transmitters with power outputs in the 1W to 20W range, not only just for amateur applications, but also with a view to using them as loads in testing FM transmitters.

When one considers that there are well over 100 types of these small bulbs, rated from .001W to 2W, and if all of these were to be considered individually, it could take a vast amount of time – and eventually one would end up with perhaps only five or so of these bulbs that would be at all suitable, so such research was not included in this article. However it did open up a field in which there may be a demand for information and may be the subject of a subsequent article.

Frequency Ranges

The use of standard screw-base ceramic or steatite porcelain light bulb sockets is entirely feasible for all of the configurations shown and will handle all amateur bands, 160 through 10. Naturally the leads from socket to socket should be as short as possible in either the series and/or parallel configurations. I found these leads can be kept to approximately 2 cm for such interconnections. Likewise, the coax termination lead should be kept to 2 cm or less.

If extra precautions as to lead lengths are observed, and the bases of the bulbs removed to enable connections directly to the stem wires, it would appear reasonable to suspect that these bulbs might be used for 6, 5, and perhaps 2 meter bands, but it is also quite evident the 2 meter band would be the practical limit.

One should be able to conjecture that light bulbs as power rf indicators are not quite the equal of well-designed power output meters which maintain their rated impedances over a very wide power output range – bulbs do not – but then, they *are* cheap in comparison.

Visual comparison of brightness is completely satisfactory for comparison purposes.

For instance, a 500W bulb connected to the 115V mains should show the same brilliance as one of the 500W bulbs as used in the 1 KW load.

Actually a transmitter supposedly putting out 2,000W PEP is putting out something less than 1,000W with average voice modulation; it would be more of the order of 500–750W average power. Remember that the light bulb is only going to show average power output, not peak, and as ham transmitters are limited to 1,000W dc input to the final amplifier, one cannot expect much more than 500–750W output (average) unless the efficiency of the final amplifier stage approaches 85% which is very unusual, although I am hearing lately that certain high-power transistors are in development which will deliver such high efficiency figures; a bit above that which heretofore has been obtainable with tubes. You should be hearing a lot more about these super-efficiency transistors in the near future; and I expect them to be appearing in certain ham transmitters within a year or so.

Naturally a CW transmitter with the final operated Class C may deliver as much as 850W with 1,000W dc input, while a DSB transmitter on phone could not be expected to deliver more than 650W with Class A or B modulation.

The research and conclusions I reached on this project brought to mind the old subject of using light bulbs in series with primaries of transformers to reduce the secondary output voltages, which is a trick which has been used for years by hams and others. The information contained herein indicates they are not only quite suitable for such usage, but in fact make quite ideal voltage regulators of a sort.

In fact, the question immediately arises as to why bulbs would not make rather ideal voltage regulators for high voltage supplies if used as a variable-resistance dc regulator in the dc leg. This again opens up a field which might bear intense investigation.

[1] Solid Dielectric RF Transmission Lines, W8LUQ, *Radio News* Oct. 1946.
Line Matching: Table of Power and Voltage Loss in DB, *Radio News* Feb. 1947.

BUILD YOURSELF A LIGHT WATTMETER

Carl Henry

Every week brings something new in the hectic field (or pasture) of electronics. Attempting to solve old problems with new components is an interesting pastime for electronics enthusiasts, but they must be careful not to put their foot in the wrong thing. One of the new components is the cadmium sulphide/selenide photocell. A semiconductor sensitive to light is not an entirely new concept, since selenium cells have been around for some time, but the degree of sensitivity makes the cadmium cell stand out.

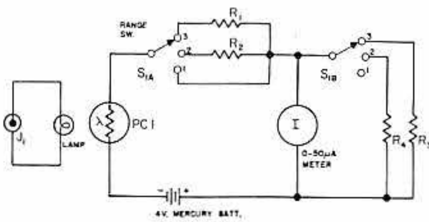


Fig. 1. Circuit of Light Wattmeter.

In measurements especially, there are many possible applications for cadmium photocells. One measurement in particular is usually difficult for the amateur, and this is power measurement. There is a way of using cadmium photocells to measure power, and I call this circuit a "light wattmeter". Operation is just as the name implies, that is, the power is used to generate light which is measured by the photocell.

You have probably realized by now that we are going to use a light bulb as a load. Now this is frequently done in amateur circles, but no one will go out on a limb as to its accuracy. Except me. We know that the ordinary lamp filament has a positive temperature coefficient. Fig. 5 illustrates the variation of a typical lamp filament resistance with input power. By keeping this in mind, fairly good accuracy can be had. Of course, if you use a different lamp, the curve will still apply, but the resistance will be different.

You can run your own graph, however, by using the setup shown in Fig. 2. Either dc or ac can be used, and since the lamp has little inductive or capacitive effect, the readings taken will be good to better than 100 mc. After you have a graph on the lamp you are using, you can effect any kind of impedance match you wish.

Using a lamp as a load simplifies the problem of power measurements because loads for this service are hard to come by. Power resistors are too inductive, and when they approach 1000 watts, they become downright expensive. However, even a 1000 watt lamp is not too expensive.

Fig. 1 shows the circuit that I used as the basis of this article. A standard 150 watt lamp was used here as a load. The photocell is mounted about five inches from the bulb. A wooden box houses the wattmeter, completely sealed internally against extraneous light. Figs. 3 and 4 illustrate the variation of resistance of the photocell with variation of power applied to the lamp. Even very small amounts of power are measureable, if the cell

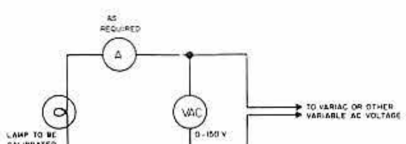


Fig. 2. Method of calibrating lamp and determining resistance.

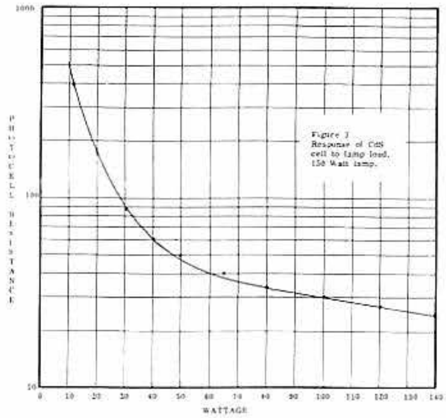


Fig. 3. Response of CdS cell to 150 watt lamp.

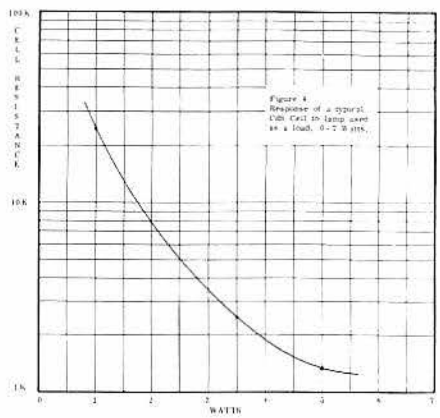


Fig. 4. Response of cell to 7 watt lamp.

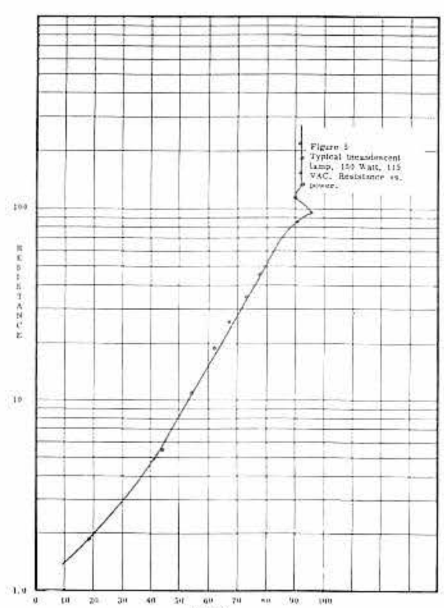


Fig. 5. Resistance versus power input, 150 watt lamp.

is shielded from external light.

The wires from the input connector to the lamp are kept as short as possible by removing the lamp base and soldering the lamp wires directly to the coaxial connector. Switch S1 selects three ranges, which can be set by the builder to anything he desires. In my case I used three ranges which cover from 0.5 watt full scale to 250 watts full scale. With some photocells a 1.35 volt mercury battery can be used instead of the 4 volt battery shown. Also, I used a 50 microamp meter, because of convenience (mine), but even a 10 ma meter will work. Don't exceed the rated power dissipation of the photocell, and remember this may derate with increasing ambient temperature. One thousand watts in a box can be a lot of ambient temperature.

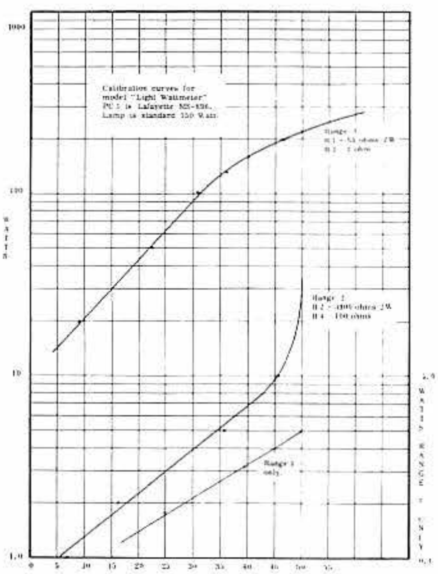


Fig. 6. Calibration curve for Light Wattmeter.

Getting back to the accuracy, if I were to tell you what the meter would read with such and such a lamp, and a given power input, your calibration would be off ten to twenty per cent when the construction was finished. The best way of getting a good calibration is something you've heard before; "if you want a job done right around here you've got to do it yourself".

Now obviously you can't calibrate the wattmeter at 14 mc, because this is what you are trying to measure to start with. Luckily the light from the lamp filament is primarily a power function, and it doesn't matter whether this is dc power, or 100 mc power.

So, to calibrate the wattmeter, apply ac or dc as you wish. Measure the input voltage and current, and read the meter. Make a graph of input power vs. meter reading, and there you have it. Fig. 6 is the graph that I use with the circuit in Fig. 1. Keep the impedance variation in mind, and select a lamp with the power impedance so that standing waves won't eat up lots of your power. As a dummy load and approximate power indictor this is not too critical, of course. But if you wish accurate power measurements, your impedance should be approximately matched.

LOW POWER LIGHT WATTMETER

Bill Hoisington K1CLL

This article describes a very useful gadget for determining the rf power output of solid-state VHF–UHF transmitters in the difficult range to measure, from about 10 mW up to 5 watts. It does not read watts directly; but by a simple comparison of calibrated pilot light brilliance, it will tell you how many watts you are putting out, to within less than 5%. It allows you to check power increases and estimate your efficiency quite close.

Principle Involved

We'll start right in with this part because, while this unit is not by any means a "trick," it does not read rf directly. You first light a pilot light as a good dummy load, matching it into the rf tank circuit of your transmitter by the normal means, also noted here.

You then switch on a second bulb of the same type by means of a battery, controlling the light output with a $1.30 wirewound potentiometer in series, as shown in Fig. 1. This pot must be previously calibrated in milliwatts, as by

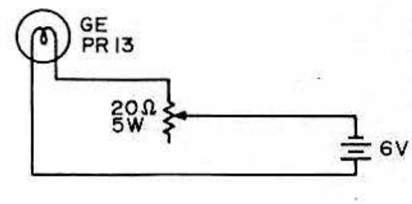


Fig. 1. The circuit supplies the brilliance "standard" for comparison. When the "standard" lamp is mounted adjacent to the dummy load, the pot permits variation of the standard to match the load. If the resistance is panel-marked in watts, a good power indication is achieved.

the method of "volts times milliamperes equals milliwatts." You then match the brilliance of the bulb lit up with rf or its dull glow at some 18 to 25 milliwatts if you're just getting your transmitter going, and read the watts on the wattmeter dial. It's astonishing how well it works, how repeatable it is, and how you wouldn't be without it once you build and calibrate it.

Brilliance Standard

Figure 2 tells almost the whole story at a glance. You can, of course, put as much calibration on the dial as you have time for. It is quite important to orient the bulb filaments in the same relation to your eyes for best matching. There isn't much in back of the panel except one 6V battery which can be obtained in any hardware store.

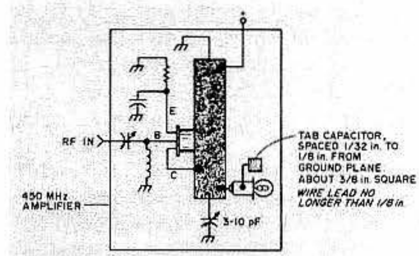


Fig. 3. Matched pilot light load for the UHF version.

RF Matching

Not that it is particularly critical, but be sure and note the need for a large range of series capacitors for the rf pilot lights as you go up in frequency. This can be seen clearly in Figs. 2 and 3. The block diagram, Fig. 2, shows a 6 meter setup. As you go up in frequency the series capacitance drops. A good matched load on 432 MHz can be obtained as shown in Fig. 3. I sometimes remove the tin base from the bulbs, but this is not an absolute neces-

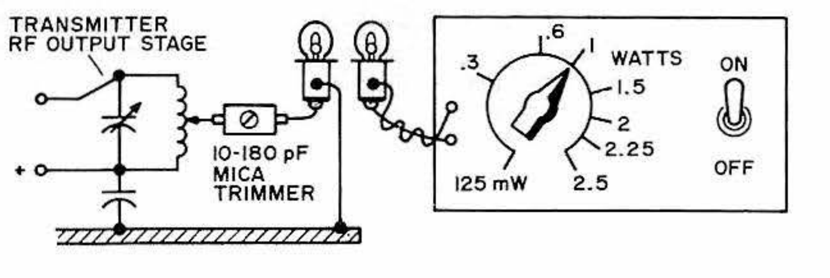


Fig. 2. A series capacitance loads the rf indicator for comparison. The capacitance value will decrease inversely with frequency increases.

sity. It is important to vary the amount of coupling, and thus the series capacity, by spacing the tab capacitor closer or further away from the ground plane, as detailed in Fig. 3. You also can use as many bulbs as you can solder onto a tuned rf inductor, even though they don't all light up with the same brilliance. You can match them all up, but you don't have to. Just check the wattage, or milliwattage, of each one and add them up for the total.

The number 48 or 49 bulb, listed at 2V and 60 mA, is rated at 120 mW, and glows dim at about 12 to 15 mW; so it can be used for low-power receiver oscillators, etc. With two other bulbs found in hardware stores, connected and matched to the rf inductor, such as the PR13 (5V at 500 mA), you can read correctly up to 5W. From there on up you're on your own, although a good variable 115V dc supply can be made up to work around 50 to 100W. I generally use a variety of 115V bulbs of different wattage, light them up with rf, and use their rated wattage.

YET ANOTHER LIGHT WATTMETER

John Meisner K5CXN

Many VHF operators would like a cheap, accurate instrument to measure rf power. The same desire is frequently expressed by operators of the HF bands. Here is a very simple wattmeter which when used with a 50Ω transmission line or load has all of the following desirable characteristics:

1. Easily calibrated to good accuracy (±5%) with your multimeter and a variable dc source;
2. Perfectly flat from dc to 450 MHz;
3. Insertion VSWR less than 1.05
4. Power readings in the 2 to 50 watt range (higher power can be measured with slight design changes);

The operating principle of this wattmeter is stark simplicity. A pilot lamp across the rf line senses a small portion of power in the line and glows brighter with increasing power. An appropriately located photovoltaic cell connected to a microammeter measures the light output which is proportional to the power flowing in the line. Of course a good deal of nonlinearity is involved in the various elements – both the lamp's resistance and its spectrum output change with heating; output of the photovoltaic cell varies considerably with both the amount and frequency of the light shining upon it. Some of these factors tend to cancel out however, because the photovoltaic cell produces some current with only infra-red lamp output at low power levels before the lamp even produces a visible glow, and the cell tends to saturate, increasing its output quite slowly at more intense illumination levels.

Probably the biggest single requirement of any wattmeter is that it must be capable of being inserted into a transmission line without disturbing the operating conditions in the line (low insertion VSWR). It might be argued that hanging a lightbulb across a transmission line will seriously affect the line impedance. Ordinarily, this is true, but the undesirable changes can be minimized and indeed approach an insignificant level if the resistance of the lamp filament is very large when compared to the line impedance. In general, a factor of 15 or more times the line impedance is sufficiently large to produce negligible effects. In the case of the suggested 10V, .014 Ampere pilot lamp, the mismatch produced in the line gives a VSWR of 1.05:1 at the power level of 1 watt. This mismatch decreases rapidly with increasing power. It falls to well below 1.01:1 at 50 watts. Another point of interest with regard to this particular choice of lamp is that it is a long-life type with a life expectancy of 10,000 hours. This implies two advantages: (a) The lamp will operate at well over its rated voltage without burnout (50.0V at 50 watts), and (b) the interior of the lamp envelope will resist darkening which would negate the wattmeter calibration. In addition, the filament structure of this type of lamp is a single-strand straight tungsten wire. The coiled type of filament structure introduces undesirable inductance into the circuit which can distort wattmeter readings in the UHF range.

The wattmeter shown is constructed in two boxes for the sake of convenience. The sensor can be located in the transmission line at any point and the meter can be placed beside the transmitter. For test work, the whole unit could easily be put into a single box. Coaxial fittings and cable were used for interconnection, but since dc only flows in this circuit, any type of wiring would be satisfactory.

The photovoltaic cell used in this wattmeter is a unit obtained from the local Allied/Radio Shack store. (Catalog No. 276-115.) Output of the cell is rated .5V at .6 mA in sunlight.

Since the cell generates considerably more than 20 mA under moderate illumination, a switching arrangement is incorporated into the wattmeter to shunt it into progressively higher current ranges with increasing power. Alternatively, a 50 or 100 milliammeter could be used with less switching at a sacrifice of sensitivity in the 1–3 watt range.

Calibration of the wattmeter is a simple process. By solution of the formula $P = V^2/R$ for voltage, the following tabulation is made for a 50Ω line impedance:

VOLTAGE (rms or dc)	POWER (Watts into 50Ω)
7.07	1
10.00	2
12.24	3
14.14	4
15.71	5
17.32	6
18.71	7
20.00	8
21.21	9
22.36	10
31.62	20
38.71	30
44.71	40
50.00	50

Using the tabulation, fasten a metered variable dc supply into the wattmeter according to the following diagram. Now simply note the reading on your wattmeter for each of the selected voltages in the table and tabulate this reading with the corresponding power in watts in a table of your own. It may even be possible to remove the front of the meter case and mark new calibrations directly on the dial. This was not possible with some hermetically sealed meters. It is best to disconnect the wattmeter from the antenna feedline for this calibration. If the meter is left with a transmission line attached and the antenna happens to be fed through a balun device with near zero resistance, the power supply, and perhaps the balun, will suffer.

It must be pointed out again that this power meter is intended for use either with 50Ω coaxial line systems with low VSWR or with 50Ω dummy loads. A coaxial line that is not "flat" (unity VSWR) or a dummy antenna that does not look like" 50Ω, which is the case with

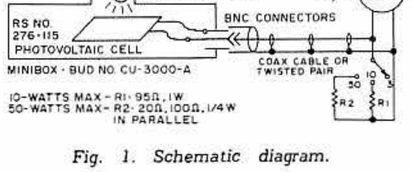


Fig. 1. Schematic diagram.

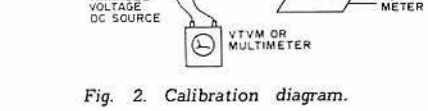


Fig. 2. Calibration diagram.

most HF loads used at VHF or UHF, may cause distorted power readings. If you have doubt about your transmitter's power output when using this meter, you should check it while using a known 50Ω load rated at the transmitter's output frequency.

I mentioned before that this power meter was easily adaptable to higher power readings. To upgrade the meter, the only change required is to insert the correct higher voltage pilot lamp having low current, long-life specifications. Suggestions for some of these are the following Dialco Lamps:

Part No.	Max Power Level (Watts)
24CS	100
48CS	200
60PSB	340
120PSB	800

A LOW COST RF WATTMETER

Mark Leavey WA3AJR

You say you just finished building that 2 meter rig and want to find out how much power you're running but can't afford to buy a wattmeter? You've been calling "CQ 80 QRP" all day with your quarter-watt wonder and nobody is answering? Then get yourself up, go down into the workshop, and build yourself a neato-keeno handy-dandy wattmeter.

If we are going to build a wattmeter, let's consider what we want. Accuracy and ease of calibration, as well as simplicity in construction are prime requisites. The meter described here is as accurate as components allow, and it's easy to build. The calibration is logarithmic, which means that a simple graph is possible, and easier than changing the meter scale.

For the mathematicians, I will present the formulas upon which this device is based, and ways of modifying it; for those of you who avoid math whenever you can, look at the graphs and skip these few paragraphs.

To spare undue complexity, assume 51Ω line – other values can be dealt with later. Perhaps the easiest parameter to measure, and one that is proportional to power, is rf voltage. A voltmeter can be made most easily with a series resistor and a 0–1 mA meter. Now let's plunge into the actual calculations.

Assume W is the full-scale meter reading in watts, Z is the line impedance, E is the voltage measured, I is the full-scale meter reading in amps of the basic meter, and R is the value of the series resistor in ohms. We know that the voltage (IR) is equal to the square root of "impedance times

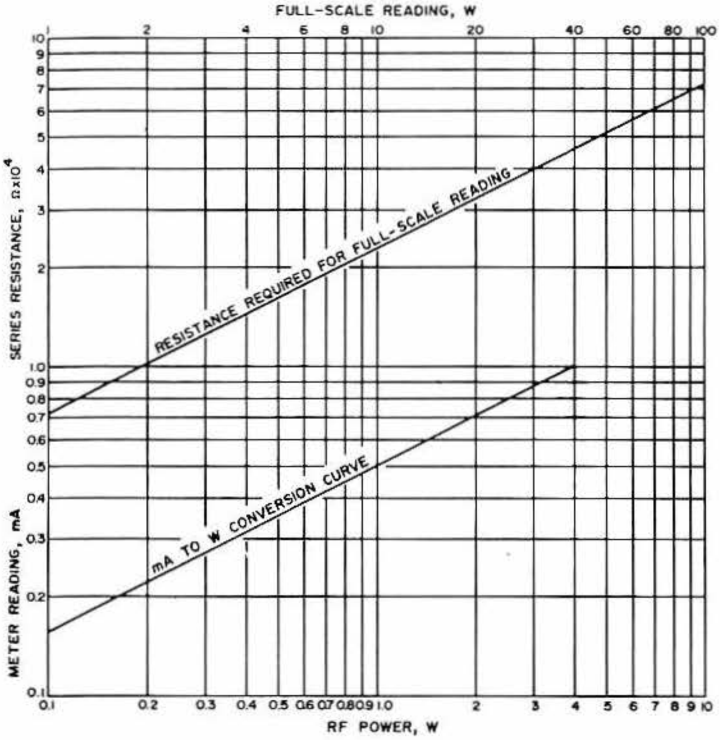
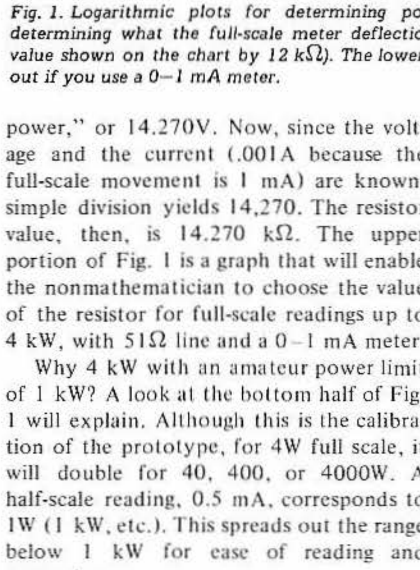


Fig. 1. Logarithmic plots for determining power. The upper curve gives resistance values for determining what the full-scale meter deflection will be (remember to multiply the series resistance value shown on the chart by 12 kΩ). The lower curve will allow you to determine your precise power out if you use a 0–1 mA meter.

power," or 14.270V. Now, since the voltage and the current (.001A because the full-scale movement is 1 mA) are known, simple division yields 14,270. The resistor value, then, is 14.270 kΩ. The upper portion of Fig. 1 is a graph that will enable the nonmathematician to choose the value of the resistor for full-scale readings up to 4 kW, with 51Ω line and a 0–1 mA meter.

Why 4 kW with an amateur power limit of 1 kW? A look at the bottom half of Fig. 1 will explain. Although this is the calibration of the prototype, for 4W full scale, it will double for 40, 400, or 4000W. A half-scale reading, 0.5 mA, corresponds to 1W (1 kW, etc.). This spreads out the range below 1 kW for ease of reading and measuring.

Now get out that soldering copper and gas pliers, and build it. As the schematic



Front view of unit.

(Fig. 2) shows, the circuit is a basic rectifying type rf voltmeter. The prototype was built in a small can of the plug-in-module variety that was scrounged from the junkbox. About the only critical part is the series resistor. The capacitors in the prototype were mica, but ceramic disks would work as well. The diode can be a 1N34A, 1N270, 1N52, 1N38A, or just about anything else. Use the old ham's rule of thumb: "When in doubt, try it out!"

Two sockets might prove more convenient rather than one with a coaxial tee as shown. Conventional minibox construction or building into a new or existing rig will be more than adequate. Point-to-point wiring is used to permit compactness and reduce lead length.

"Fine," you say, "but I don't have a huge mound of test equipment. How do I calibrate it?" That is the beauty of it – you don't! If the series resistor is accurate, the meter will be self-calibrating to a log scale. Remember, you know R and Z, and the full-scale W. Now assume a half-scale

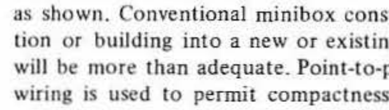
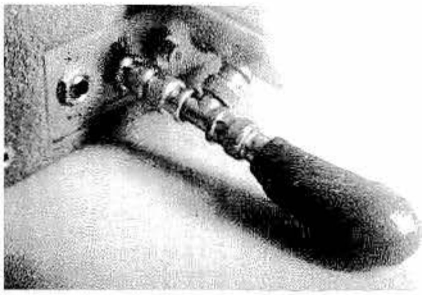
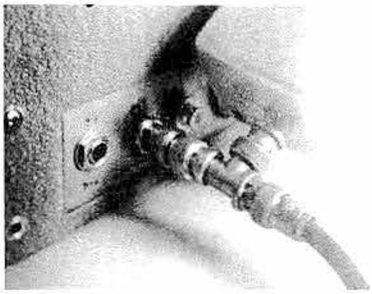


Fig. 2. Schematic diagram of the simple, accurate, and easy-to-build rf wattmeter.



Connection to transmitter with dummy load (see text).

reading, I = 0.0005, and calculate W for half-scale. Plot these two points at 1.0 and 0.5 mA on Fig. 1, and connect by a straight line, which you may extend the length of the graph.



Connection to transmitter with antenna connected.

Install the meter through a coaxial tee at your antenna connector, or through some other predetermined means, and terminate with a dummy load. The one seen in the picture is three 150Ω resistors in parallel, dipped in epoxy, shielded with a copper braid, and installed on a BNC plug. Apply power and read the meter. That's it! The meter can be used with an antenna if your swr is below about 1.2:1.

So what did I promise? A low-cost, rf wattmeter that is inexpensive enough for the Novice, practical and useful enough for the General, and "Extra" accurate. Go raid the junkbox, and add a worthwhile piece of gear to your shack.

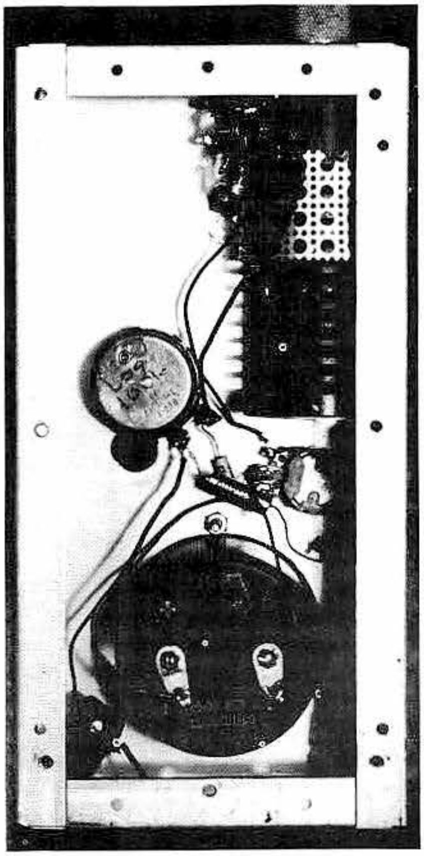
RF POWER MEASUREMENT USING HOT CARRIER DIODES

Frank Jones W6AJF

Two rf wattmeters are shown here, one with a range of 25 mW to 10W and the other covering the range of 5 to 300W. Both are useful from low radio frequencies on up through 450 MHz.

The low-power version (Fig. 1) makes use of a 20W Sierra dummy antenna built into the meter case, though the metering circuit only goes up to 10W. If the maximum is to be 20W, the reference meter reading could be about 45 μA instead of 30. The minimum power reading would be doubled. In this wattmeter, the power range potentiometer is calibrated and only a reference line on the meter is used when making rf measurements. The dummy 50Ω antenna resistor is rated up to 1000 MHz so is excellent from 450 MHz down.

The range potentiometer had an audio (nonlinear) taper. By connecting the "high" resistance end to the diode, the watt range scale is spread out quite well in the 0.1–10W range. The hot carrier diode, an HP 2900, has a 10 PIV rating, which means that the rms rf voltage across it should be less than 3V for safe operation. At 10W of rf power, the rms voltage would be a little over 22V, which means a voltage



Bottom view of 10W unit with the rf dummy antenna clamped in one corner.

Top view of low powered rf wattmeter covering .025 to 10W. Built into a 8x4x2 chassis with wire screen bottom plate for ventilation.

divider is needed to keep the applied diode voltage down to about 2V. An HP 2800 diode with a 75 PIV rating would be more desirable, especially if the meter was to be calibrated for 20W maximum. This diode is about $1 and has a little higher capacitance, which would require a different shunt capacitance across parts of the resistor divider to make the device work with the same power range calibration.

The divider should use ½W resistors of the carbon or metal film type, since these units are part of the rf circuit. It is better to use three ½W 300Ω resistors in the string rather than a single 900Ω 2W resistor: this is because the rf resistance characteristic is usually better in ¼ or ½W types in certain ranges of resistance. Every resis-

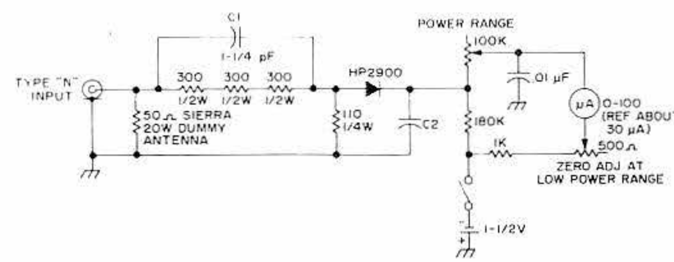


Fig. 1. .025 to 10W RF wattmeter.

tor has some inductance and shunt capacitance which becomes part of the voltage divider. The diode shunt capacitance is in parallel with that of the 110Ω ¼W resistor in Fig. 1. However, nearly any combination of resistor sizes can be equalized within 10 to 20% over the desired frequency range. This divider is across the 50Ω dummy antenna, so should not shunt the value down to less than 49 or 48Ω. This divider has to dissipate a little rf power also. Its total resistance should be at least 20 times as high as the dummy antenna load resistor.

The values shown in Fig. 1 are just about the minimum that should be used. Too high values makes it more difficult to extend the frequency range to the upper end, though it can be done, as was discovered in the higher-powered wattmeter of Fig. 2.

All diodes are poor rectifiers at applied rf voltages below their forward bias values of 300–700 mV (peak). By using a forward dc bias voltage to make the diode conduct at least 5 or 10 mA, the detection sensitivity is increased as much as 5 or 10 times. This requires a small battery, a couple of fixed-value resistors, and an adjustable pot to balance this current out of the meter when measuring rf powers below 100 mV. If the power range is limited to a minimum of ¼ or ½W, no bias circuit is needed in this 10W instrument. The range scale in either case has to be hand calibrated.

A low-powered radio transmitter or exciter can be used as a 10W power source when calibrating the power range pot scale. The transmitter can use stage detuning to reduce power outputs down to the lower values needed. Many swr meters have watts of power calibration and one of these can be put in the coax line to the rf wattmeter for calibration service. A more accurate calibration can be made by comparing the power readings against some reliable commercial rf wattmeter within its frequency range and calibration charts. This scheme is usually necessary for checking the calibration at VHF or UHF. Another method is to use an accurate rf voltmeter across the dummy antenna connection to ground and read the power values in watts = E^2/R. For example, 5V (rms) squared is 25; and divided by 50Ω is equal to 500 mW.

The Sierra 50Ω dummy antenna has no connection available at the high end of the resistor, which terminates in a type N fitting. The metering circuit has to connect to this point as close as possible by getting into the inner conductor of a coax fitting, or by drilling a 3/8 or ½ in. hole through the shell of the dummy antenna close to the rf fitting end. This can be done and the first 300Ω resistor in the voltage divider soldered to the inner connection to the large 50Ω resistor. A long 1/8 in. diameter soldering iron tip is needed. The divider resistors, diode, and four .001 μF stud-mounted bypass capacitors were all mounted around this large hole in tapped 6-32 holes for the four capacitors. Larger values of bypass capacitors can be shunted across these 0.001 μF values to ground to extend the frequency range down to low rf or even af values. For example, a .02 μF capacitor shunt would allow operation to 2 MHz. A miniature 50 or 100 μF electrolytic shunt would function at audio frequencies down to 300 Hz. The diode must have a low-impedance path to ground over the desired frequency range to function as a peak rectifier and get as much dc output voltage as possible for the meter circuit. The microammeter in series with a variable range resistor is simply a dc voltmeter. The diode rectifier converts rf voltage to dc, so the diode should be equally efficient over the whole rf range.

The 5–300W unit was built to use with a large dummy antenna rated up to 500 MHz, which is a massive unit external to the box shown in the photographs. Quite a bit of rebuilding went into this device to make one calibration of the range potentiometer fit all frequencies from 450 to 2 MHz. The input and output coax fittings had to be finally mounted so the inner conductor tips could be soldered together and the resistor divider connected to this point. The latter consisted of two 4300Ω 2W carbon resistors and a 68Ω 1W resistor in series to a copper sheet inside of the aluminum box.

The watt range variable resistor was a 500 kΩ linear potentiometer which was limited to a lower value by shunting it from the moving arm to the diode connection end with a 220 kΩ resistor. This gave a maximum power reading of 300W when

Top view of 5 to 300W metering circuit for use with external high powered dummy antenna.

the reference line was drawn on the meter face at 12 μA. The import, low priced, 0–30 μA meter had a large meter scale. A smaller 0–50 μA meter would have been usable, since the meter is used only as a reference. The range pot knob is adjusted when rf power is applied to run the meter reading up to the line drawn on the meter scale face.

The circuit shown in Fig. 2 was equalized to within about 15% error over the range of 2 to 450 MHz by shunting a 5 pF capacitor across the 68Ω resistor in the rf divider.

Calibration of this device was made at 144 MHz using a transmitter having up to 400W available carrier output. The meterizing unit was connected to a large Bird rf wattmeter at the external fittings of the latter. Several thermocouples had to be used to cover the wide range of power for the calibration. This required reading a chart curve for each Bird wattmeter reading and using correction factors for frequency in order to obtain the actual watts of rf power. Now, the large unit is used without the thermocouples, charts, rf choke, etc. simply as a dummy antenna. The new metering circuit connects directly into the antenna fitting, with a few feet of 50Ω coax over to the transmitters being tested.

This power measuring device can be used in any 50Ω coaxial line to monitor the actual power going toward the antenna. The swr in the line should be low, or near unity, in order for the calibration to be reasonably accurate.

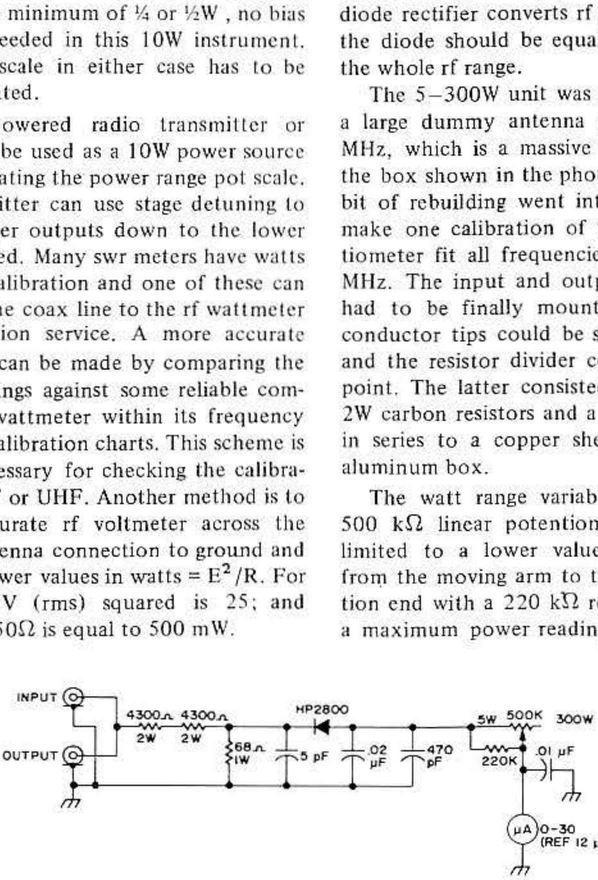


Fig. 2. 5 to 300W RF wattmeter metering circuit. External 300 or 400W during antenna load.

VHF DUMMY LOAD WATTMETER

Glen Zook K9STH

The unit

The unit described herein is similar to some 60 watt units which may be found around many commercial two-way radio shops. This dummy load has provision for connection to an external relative output meter. This external output meter may become an accurate wattmeter if the following criteria are met:

1. Frequency bandwidth of $\pm$10% of calibration frequency.
2. RF output kept within power dissipation of dummy load.
3. Accurate initial calibration.

These criteria may be easily met in amateur vhf operation if only one band is considered for each set of calibration data. Since most vhf amateurs operate on 50 mhz, 144 mhz or 432 mhz, the $\pm$ 10% frequency limitations may be easily met. This limitation gives a 10 mhz bandwidth at 50 mhz, 29 mhz bandwidth at 144 mhz, and 86 mhz at 432 mhz. The limitation to the power ratings of the dummy load is only common sense, for if a resistive network is overloaded, the impedance may be drastically increased, caused by damage to the load resistors. The calibration limitation may be overcome if a standard, previously calibrated unit, or commercial unit is used.

The unit consists basically of 16 220 Ohm resistors in a series parallel arrangement. The metering circuit consists of a germanium diode pickup with necessary rf filtering. The meter movement is generally a vom, but any 50 ua meter movement should suffice. Exact physical layout is not extremely critical, but it is suggested that the layout be made similar to the unit shown in the accompanying photographs. This unit is acceptable for 60 Watt output transmitters without modification. The power capability may be increased to about 200 Watts if the resistive network is suspended in 1 quart of oil. If this is done, care must be taken to keep the metering circuit out of the oil. The lead from the diode to the resistive network must, of course, be partly submerged, but keep the diode itself out of the oil. I do not personally use this arrangement, but I know of two units which have been in use at a large Southeastern two-way radio shop for several years. The same shop has incorporated a range switch with several meter shunts for various maximum scale power readings. This feature is especially useful to the amateur vhf FM operator who may be working with equipment of from ½ to 250 Watt outputs. The schematic appears as Fig. 1, and the basic circuit for various meter shunts as Fig. 2.

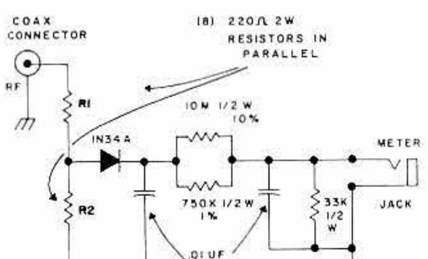
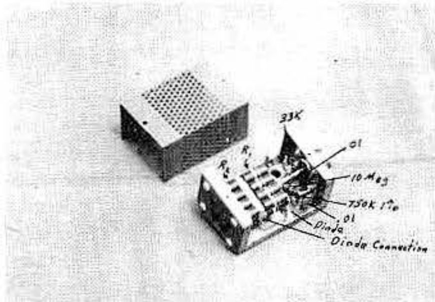
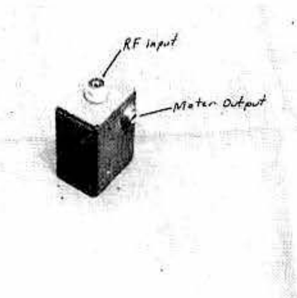


Fig. 1. Schematic. R1 and R2 consist of eight resistors each, in parallel.



Parts layout and interior view of Dummy Load – Wattmeter



External view.

Calibration

Calibration is best accomplished by using a Bird "Thruline" or similar commercial vhf inline wattmeter. Second choice is a Bird "Termaline" or similar dummy load-wattmeter. In both cases, a graph should be created by plotting meter divisions on the horizontal axis, and power on the vertical axis. The meter shunt should be placed at minimum resistance and increased to give maximum reading at the desired power level (this holds primarily true for units using the metering circuit of Fig. 2) or, if a vom or vtvm is being used the range switch should be placed on a high voltage setting and reduced a setting at a time until the desired reading is obtained. The transmitter should be adjusted for various power levels on the standard wattmeter and the voltage or current reading on the new meter recorded on the graph. In the case where the standard meter is of the dummy load-wattmeter type, it will be necessary to switch the coax from one unit to the other. Do not retune the transmitter, for each unit will present almost the same load to the transmitter (50 ohms). Take the reading and record as with an inline type of meter. The points on the graph should now be connected with a smooth curve (use of a draftsman's

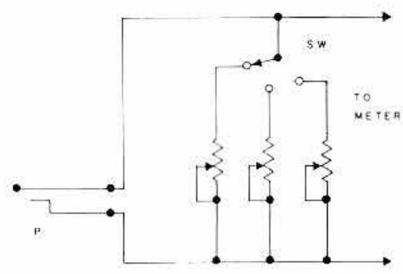
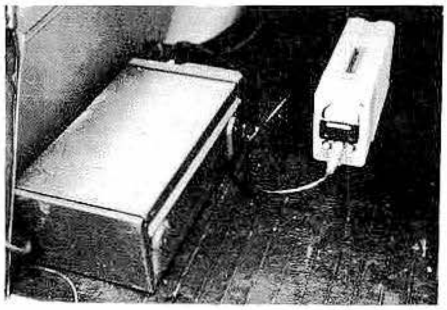


Fig. 2. Metering shunts.



Using the Dummy Load – Wattmeter to check output of FM unit.

range switch is used, it will be necessary to calibrate for each switch position. Also, if multi-band use is expected, the graphs must be made for each band. Use of the wattmeter now requires only the connection to the transmitter, setting of range switch to the proper level, and reading the graph.

Uses

The uses of this dummy load-wattmeter are as varied as the amateur mind can devise. One very important use is determining the losses of 50 ohm coax. Measure the output of the transmitter at the transmitter. Then measure the output at the end of the length of coax. The losses in the line become apparent. The loss in db may be calculated by the standard power ratio formula, 10 $\log_{10}$ Power out of coax/Power into coax.

Another use is the determination of efficiency of final amplifier stages. This efficiency may be calculated by Power out (measured by dummy load-wattmeter)/Power in (measured by plate current/plate voltage meter) x 100%. A third use is determining once and for all which amateur really has the most output. This list may be expanded by the builder to suit his own tastes.

Conclusion

This dummy load-wattmeter is not a Bird "Termaline" nor should it be regarded as a substitute for any other laboratory equipment. However, with a little care in calibration, (assuming a 5% accuracy standard is used for initial calibration) the accuracy should be within 10%, and this, my friend, is not bad for a wattmeter costing less than $10.

Chapter IV

Measure Your Field Strength and Frequency

THE RF SNIFFER

Jim Kyle K5JKX

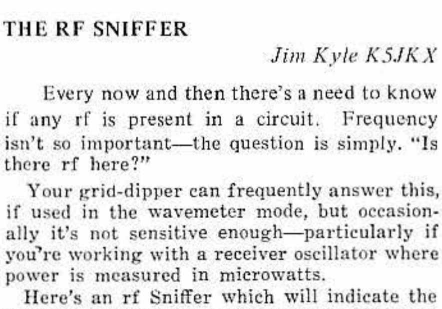
Every now and then there's a need to know if any rf is present in a circuit. Frequency isn't so important—the question is simply. "Is there rf here?"

Your grid-dipper can frequently answer this, if used in the wavemeter mode, but occasionally it's not sensitive enough—particularly if you're working with a receiver oscillator where power is measured in microwatts.

Here's an rf Sniffer which will indicate the slightest trace of rf in a circuit. In addition to checking receiver oscillators, it's a perfect gadget to ensure perfect neutralization of a transmitter final.

Connect the components as shown in the schematic. Use long-nosed pliers as a heat sink between the diode and the solder joint when wiring, to prevent diode damage. Note that the pickup loop of 14 gauge wire is insulated with a strip of spaghetti.

Mount capacitor and diode on back of meter with shortest possible leads. Attach pickup loop directly to negative meter terminal; it's stiff enough to do without other mechanical support.



Amplifier Neutralization—Couple the Sniffer to the antenna terminal with a temporary two-turn link around the pickup loop. Remove plate and screen voltage from the final amplifier. Apply drive. Adjust neutralization for minimum indication on the Sniffer—but don't expect to be able to get it down to zero.

Oscillator Checking—Place the pickup loop near the oscillator coil. If the oscillator's working, the Sniffer will indicate rf. Touching either the grid or plate lead (use an *insulated* tool for this test, not your fingers) should reduce the Sniffer's indication.

Receiver Troubleshooting—Check the oscillator as described above. If it's okay, next check the mixer plate coil by placing the Sniffer pickup loop near it. If you get an indication here, move to the first if stage and place the pickup loop near the plate pin of the tube socket. Proceed through the receiver until you lose the indication. The trouble is somewhere between the last indication and the point at which it disappeared.

Field Strength Meter—Couple a short antenna to the pickup loop by two turns of wire around the loop. Field strength will be indicated in a comparative manner by the meter. It cannot be calibrated, but proves useful in tuning mobile or beam antennas, etc.

SWR Measurement—(Parallel lines only). Move the Sniffer long the line. Mark maximum reading and minimum reading over a half-wavelength. Divide minimum into maximum. The quotient is, roughly, your VSWR. This method is by no means exact, but will indicate whether the line is under or over a 2:1 SWR.

UHF Frequency Measurement — Set up Lecher wires. Couple the rf Sniffer lightly to the tank circuit instead of using a flashlight bulb. Use Lecher wires in normal fashion, reading Sniffer indications for maximum and minimum. This is much more exact than the normal methods.

Improvised Grid-Dipper—If you have a signal generator available, it can be used with the rf Sniffer to serve as a "grid-dip" meter to locate resonance for any tank circuit. Couple both the generator and the Sniffer lightly to the unknown tank. Vary generator frequency. A sharp rise in Sniffer indication indicates the resonance point.

THE PINK TICKET REJECTOR

A. D. Taylor GW8PG

Hams sometimes get into trouble with the FCC because they have made a mistake in tuning a frequency multiplier or PA stage. For example, if the multiplier stage following a 3.5 MHz oscillator is accidentally tuned to 10.5 MHz instead of 7 MHz, the PA can be loaded on 10.5 MHz; and if this is done even a short transmission is likely to produce an unwanted "QSL" from the FCC! Mistakes like this can be prevented by using the simple, easily built absorption wavemeter shown in Fig. 1. Only one coil is required in this meter, the low frequency range being obtained by switching a padding capacitor in parallel with the variable tuning capacitor. With switch S1 open the tuning range is approximately 6.8 to 30 MHz, and with S1 closed it is approximately 3.5 to 6.8 MHz.

Construction of the wavemeter is simple. It can be put together in a metal utility box, on a wooden panel and baseboard, or even in a cracker can of the right size. The coil can be wound on any type of ¾ in. diameter form. If nothing else is handy, a short length of dowel could be used. The coil winding consists of 7 turns of 20-gage wire, close wound. Both the tuning capacitor (C1) and the padding capacitor (C2) should be 500 pF components, but the values of the other components are not critical.

Any meter having a full-scale deflection between 100 µA and 1 mA can be used. If the wavemeter is built in a metal box, L1 must be mounted outside the box. A slow-motion drive is not needed. If C1 is fitted with a pointer type knob and a cardboard scale is cemented onto the front panel, the calibration points can be written on the scale in ink.

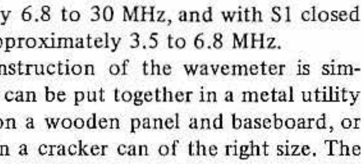


Fig. 1. L1 – 7 turns 20 gage enameled copper wire, close-wound on a ¾ in. form; C1 – 500 pF variable capacitor; C2 – 500 pF fixed capacitor; C3 – Fixed capacitor, any value between 1000 pF and 0.01 µF; D1 – Silicon or germanium; M1 – Moving coil-meter (100 mA–1 mA).

When it came to calibrating the wavemeter I thought of a simple method that I have not seen described before. I soldered about 2 in. of wire onto one end of L1, and about 10 ft of wire onto the other end. I then connected the short lead to the antenna terminal of my receiver and strung the 10 ft of wire up as a temporary antenna. I then tuned the receiver to a steady signal at each frequency at which I wanted a calibration point, and adjusted C1 until the strength of the received signal suddenly dropped sharply, indicating that the wavemeter was tuned to the frequency of the signal. I was then able to mark this frequency on the cardboard tuning scale. The drop in signal strengh was very sharp so calibration was easy. Once enough calibration points had been obtained the temporary wires were unsoldered and the wavemeter was ready for use.

The only frequency which may require a little adjustment is 30 MHz. If the wavemeter will not tune as high as this, push the top turn of coil L1 about 1/8 in. away from the other turns. This should reduce the inductance sufficiently; a spot of cement will hold the turn in its new position.

To use the wavemeter for checking a transmitter, bring coil L1 close to the tank coil of the stage being checked, apply power to the stage and rotate C1 until a maximum reading is obtained on the meter. The output frequency of the stage can then be read off from the wavemeter tuning scale.

The wavemeter can also be used as a radiation meter for tuning up single-wire antennas. If it is tuned to the transmitter output frequency and placed near to the antenna wire, maximum reading on meter M1 will indicate maximum output power from the transmitter.

Many readers will have realized that the calibration method I suggest uses the principle of the rejector circuit. That is why I have called the little gadget "the pink ticket rejector"!

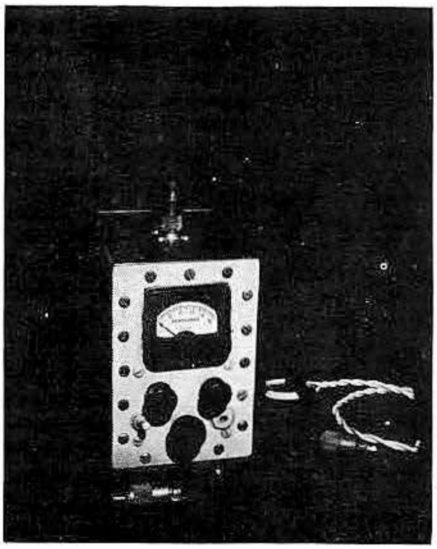
A USEFUL ACCESSORY FOR THE HAM SHACK

Rex Morris W2WHX

BECAUSE we are dealing with something we cannot see, namely electrons and electromagnetic radiation (we only see their effects), we must acquire the ability to use test equipment, in order to understand and find our way in this invisible realm.

The piece of test equipment about to be described is one of the more useful instruments that the amateur should have in the shack. While this instrument serves primarily as a field strength meter, it will also serve as a phone monitor, neutralization indicator and a sensitive wavemeter.

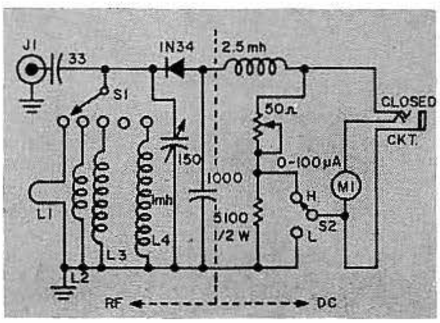
Referring to the circuit diagram, meter M1 is a sensitive instrument which indicates the pressure of rf when the device is used as a field strength meter, wavemeter or neutralization indicator.



To use this instrument as a wavemeter, a pickup loop is substituted for the short whip antenna at the top. Switch S1, the band switch on the right of the panel, is placed on the proper position. Coil L1 tunes the vhf range of approximately 90 mc to 170 mc (2 meters). L2 tunes 28 mc to 100 mc (10 meter and six meter bands). L3 tunes to 7 mc to 30 mc (40, 20, 15 and 10 meter bands). L4 tunes from 2 mc to 7 mc (80 and 40 meter bands). With switch S1 on the proper tap, condenser C2, on left of panel, is used to peak the reading on meter M1. Using a calibrated dial, frequency may be read directly. Toggle switch S2 is a high-low range switch for meter M1, providing a means of keeping the meter on scale and protecting it against burn-out. Potentiometer R1 (center of panel) is a vernier shunt control, also for keeping the meter on scale.

For use as a phone monitor, rf should be fed into the input jack with a link or pick-up wire. Once again the LC circuit is resonated to the frequency we desire. Earphones inserted in jack J2 will open the meter circuit and allow you to monitor the signal. Switch S2 is placed in the Hi position.

Field strength readings can be taken by using a short pickup antenna. Again the LC circuit should be tuned to resonance. Meter M1 will give an indication of field strength.



With switch S2 in the Hi position the meter is very sensitive and potentiometer R1 is a variable shunt providing much range of scale adjustment. For use as a remote reading field strength meter an external microammeter (with up to 200 feet of wire) may be plugged into J2. For making transmitter adjustments this is a very desirable feature.

Now notice that one position on the bandswitch S1 is vacant, this vacant position provides a very broad band—low sensitivity position for those extremely high rf fields where even R1 and S2 cannot provide enough attenuation.

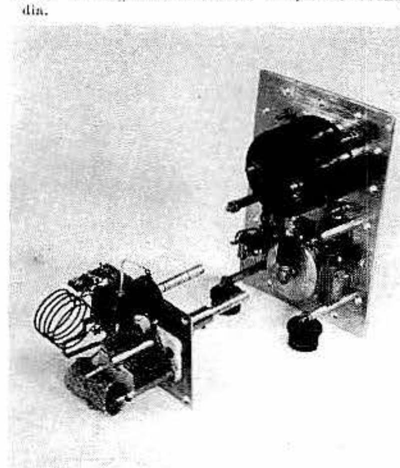
Neutralization measurements are made by coupling the instrument through a pick-up link to the tank coil involved, with S2 in the Lo position. When the instrument is tuned to resonance it becomes a very sensitive rf indicator. It is so sensitive that it will readily be seen that complete neutralization exists in theory only.

As in all simple gadgets there are a few simple construction techniques which make the difference between gadget and instrument. In this case the important thing to keep in mind is that from the antenna to the crystal is the rf portion, and from the crystal to the jack J2 is the dc portion (with audio superimposed). With this in mind, construction is such that the two parts are separated, thereby giving some measure of protection from rf energy to the very sensitive microammeter M1. Also note the extensive use of sheet metal screws on the aluminum case. The only rf we want to enter the case is the rf we are attempting to measure via the antenna jack. Note again, we have here an instrument for detecting electromagnetic radiation, from approximately 170 mc to 2 mc. We now have an instrument for visualizing what cannot be seen.

The usefulness of this instrument is limited only to one's ability to apply it and interpret the results it gives. These only come with experience, trial and error and determined application.

Coil Data

L1—One turn hairpin loop.
L2—5 turns of #18 enamel wire space wound 1" dia.
L3—24 turns #22 cloth covered wire, close wound, ⅝" dia.

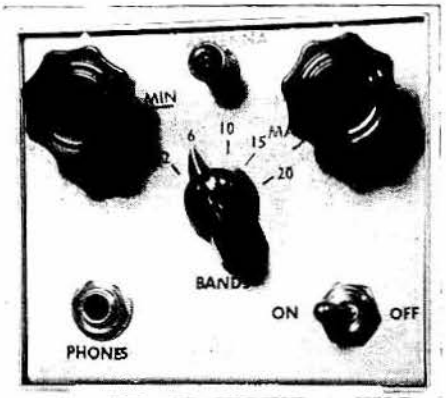


TWO THRU TWENTY FSM

Howard Pyle W7OE

I used a small LMB aluminum meter cabinet with a hole for a 2" meter; any equivalent cabinet can of course be used. With a small enclosure such as this (4"x4") the meter occupies the face of the cabinet and all controls are on the rear. Using a somewhat larger housing both the meter and the control knobs can be placed on a front panel if you prefer.

Rather than wind up the three coils I found that the J. W. Miller Company RF chokes with minor modifications were admirably suited for a compact job. One each of their catalog numbers 4606, 4588 and 4580 were required to cover the three frequency spreads from 2 through 20 meters. The #4606 coil should have five turns carefully removed, to cover the 10-20 meter bands; remove three turns from #4588 for six meters and two turns



from the #4580 coil to handle 2 meters. These can all be resonated with a 50 pf midget variable tuning capacitor; a Hammarlund HF-50 or the equivalent is excellent. Any of the small multi-point selector switches can be used for band switching. A JBT lever switch type SS-14-ILS will handle the job or, if you prefer a rotary switch you can use a Mallory type 3215J as I did, leaving two positions unused. (I might want to add a couple of coils and try 40 and 80 later!).

Resistors R-1 and R-2 shown in the schematic, need be only ½ watt. A single flashlight cell will serve for the battery although I chose a 1.4 volt mercury transistor battery to conserve space. Other items shown on the schematic are obvious and all parts are readily available from most electronic parts distributors as well as from the electronic mail order houses.

Build this little F/S meter and know what your VHF outputs are doing. If you want to check your modulation quality, a phone jack may be added as shown, making this little gadget really versatile.

Side view of the FSM.

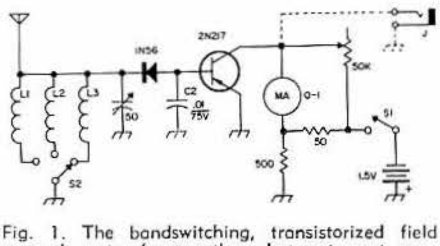


Fig. 1. The bandswitching, transistorized field strength meter for two through twenty meters.

AN AMPLIFIED, CALIBRATED SIGNAL STRENGTH METER

J. L. Iliffe VE3CES

Recently, I had the problem of tuning a four element quad. As you may or may not be aware, these beasties are supposed to be tuned from the rear for minimum signal. A quick check showed none of my friends had a signal strength meter, so I prepared to degrade myself and buy one. A look at a few prices convinced me to build.

Since I wanted some other information on the quad, like front to back ratio and the effect of more or fewer elements, I decided to add a calibrated attenuator and enough gain to make a fairly wide input range. It also had to be cheap!

The result is shown in Fig. 1.

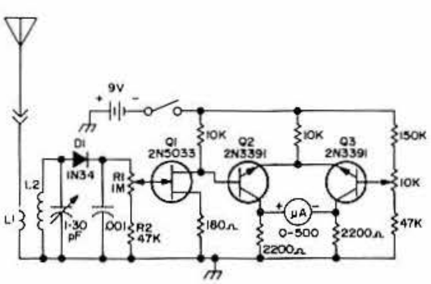


Fig. 1. Diagram of the field strength meter.

To use the normal rf attenuator method of switched T-pads requires complicated shields and quite a few resistors. Also the attenuator has to be terminated in its characteristic impedance to read correctly. To bypass this problem I first detect the rf, then attenuate the dc. This has the added advantage that the circuit is no longer frequency sensitive.

The incoming rf is tuned by C1-L2. C1 can be any small variable. I used both sections of a dual 15 pF because my local surplus store has them for 60¢. For VHF use only 1 section.

L2 is wound on a plastic pill bottle about 1" in diameter and tapering to 7/8". To cover 13–24 MHz, I used 11 turns spaced over about an inch. L1 is 2 turns over top of L2. I tried bandswitching with another pill bottle fastened on the other side of the shield from L2. The idea was to bandswitch another frequency range but I find it more convenient to wind on coils as needed. Use the grid dipper to get you in the ballpark. I have used this meter as high as 72 MHz without trouble. D1 can be any diode. I used a 1N34 because I could then specify it and know it would work, but I tried a computer type which also worked. If you prefer the meter to peak rather than dip, reverse D1.

Rectified rf from D1 is put on the top of R1, the calibrated attenuator. R2 in series with R1 gives the 0 dB point at its junction. For a 30 dB range, R2 is 47K if R1 is 1 MΩ This doesn't quite fill the range but is close. Changing the value of R2 will change the range but 30 dB is considerably more than the F/B ratio of most beams.

Q1 is a 2N5033 FET. The high input impedance of Q1 allows us to set the calibration of R1 directly by dc voltage measurements on the VTVM since it does not draw any base (gate) current. It is a p-channel device. If you use an n-channel type you will have to change the entire biasing of the circuit and also reverse D1.

Q2 and Q3 form a differential amplifier to drive the meter. Q2 is necessary to avoid loading Q1 and I had quite a bit of trouble balancing the meter against battery voltage changes until I added Q3. It will now operate from 8.5–9.2 volts with no trouble. The 10K pot in Q3's base centers the meter. The meter I used is a 250 μA tuning meter with no markings on it except a red/white/blue bar. This is all you need since we calibrate on R1, not the meter.

Operation

The meter is quite sensitive and with a two foot antenna I could get a reading several hundred feet behind my quad at 60 watts input. First tune the input (which is quite sharp) with the attenuator set at zero. This is the least sensitive position. Now set the meter for a convenient reading near the center scale with the incoming signal still on using R3. Adjust your antenna. When you feed it power again the reading will not be quite on scale on the meter but turning up R1 will allow you to put the meter back to the original position. Do not touch R3. The reading on R1 is now the increased gain in dB needed to bring the signal back to its original strength. In other words, the decrease in signal strength.

Note that during measurements you need a received signal to use R1. With no signal the meter will be off scale.

I have also used the meter to align oscillators and doublers in my two meter receiver. A probe can be made for this from two turns of wire on the end of a piece of coax. The high gain available allows the pickup loop to be quite far away which reduces detuning. Adjustments show up well on the meter.

FREQUENCY MEASURING EQUIPMENT AT MICROWAVE FREQUENCIES

Silas Smith WA9VFG

This article is not intended to give the theory, but rather a practical solution to the building and use of wavemeters at micro-vave frequencies.

In microwave work, frequency is one of the most important measurements. It must be understood the wave length in the devices described here is not the exact frequency wave length. A well-constructed wavemeter that has been calibrated can be very precise. They can be within 1.5 MHz at 10 GHz or less than half of a MHz at 1250 MHz. Temperature has some effect on the frequency. Most commercial wavemeters are constructed of Invar, a metal that changes very little with temperature. Some parts are of bi-metal construction to compensate for temperature. For the average experimenter, brass and copper will have to suffice. Although silver plating is desirable, it isn't an absolute necessity. Frequency at microwave frequencies can be measured by three methods: wavemeters, slotted lines, and frequency comparisons. All of these methods are used commercially. The frequency comparison is usually used in the laboratory to calibrate the wavemeter and the slotted line. As a general rule, any method of frequency measurement used at lower frequencies can also be used at the microwave frequencies, but are not always practical. The resonate cavity as a wavemeter is used in microwave measurements.

There are three types of cavity wavemeters: the transmission type, Fig. 1A and 1B, the reaction type, Fig. 1C, and the assorption or absorption type, Fig. 1D. All are resonate cavities. The way in which the wavemeter is used determines the type.

All wavemeters are adjusted for maximum readings except the assorption type. The assorption is adjusted for a dip in power output. The most popular wavemeter used

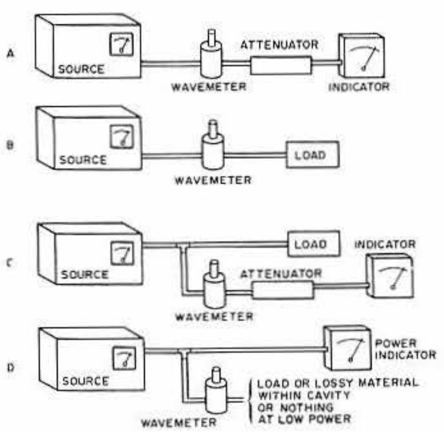


Fig. 1.

by the beginner is the open circuited transmission line type, Fig. 2. This type of wavemeter is the equivalent of lecher wires. (Open circuit refers to the standing wave within the cavity, not the physical construction except as it pertains to the frequency wave length.) The practical physical dimen-

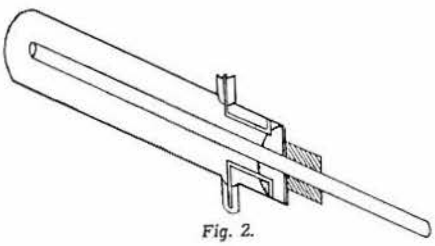


Fig. 2.

sions are not many. The inner circumference of the main tube should be less than one wave length at the highest frequency to be measured. The rod should be small compared to the tube. If inductive coupling is used, the inductive coupling should be close to the shorted end. For probe coupling, the probe should be close to the middle. The open circuited transmission line is generally used in two ways. This type can be used "in line' (Fig. 1B) as it has very little loss when it is resonated. However, it should be removed from the line before transmitting, as it will act as a narrow band filter. The half wave length is the measurement between the two successive points at which the generator will load to maximum, as the rod is inserted or withdrawn.

Another method in the use of the open circuited transmission line calls for the use of an additional circuit, as in Fig. 3. The circuit is a simple crystal diode detector connected to a microampmeter. The diode and condenser are usually built into the connector, as the leads should be kept as short as possible. The half wave length measurement is made on the rod between two successive maximum readings on the meter, as the rod is inserted or withdrawn. See Fig. 1A and 1B for the setup.

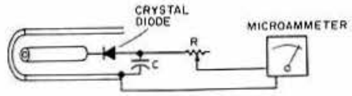


Fig. 3.

The quarter wave coaxial cavity is actually a shorted coaxial line one quarter wave length long (Fig. 4, 5, 6). As illustrated in these figures this type makes a very good cavity to use as a standard. To calibrate, a chart is made of the micrometer settings at different frequency wave lengths from a calibrated source generator. Don't tell them so, but the Public Relations Department of the Telephone Company may help you here, if they have any microwave technicians close by. The quarter wave coaxial cavity can be either physically open or closed. If closed, the closed end should extend at least a quarter of an inch beyond the center conductor at its lowest frequency. The closing of the end will lower the resonate frequency. Probe (capacitance) coupling as used for coupling in Fig. 5 will shorten the center conductor, and loop (inductive) as used in Fig. 4 will lengthen the conductor. In Fig. 4 we change the length of the center conductor to change its one quarter wave length. In Figs. 5 and 6 the center conductor remains the same, and we change the resonate frequency by capacitance. This method makes it necessary to construct the center conductor very short as compared to the full quarter wave length as in Fig. 4. These devices are not longer, so caution must be used when calibrating. The closed wavemeter as indicated in Fig. 7 is a shorted coax line at each end. The wavemeter uses a shorting plunger which is movable along part of its length. If used as the quarter wave coaxial cavity, the center conductor must be longer than a quarter wave length.

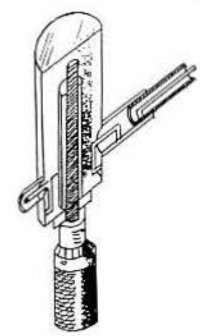


Fig. 4.

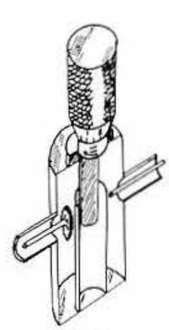


Fig. 5.

Up to this point we have covered most of the wavemeters that could be used from around 144 MHz up to approximately 3000 MHz. 1000 MHz to 3000 MHz are usually called the lower microwave frequencies. If the inner circumference of the outer tube is kept less than one wavelength, these wavemeters will operate in the desired TM mode.

There are four ways to couple energy into a wavemeter, loop (Fig. 4), probe (Fig. 5), direct (Fig. 6) and slit (Fig. 8). The most commonly used is the loop, as it has very little effect upon the electric field. The usual methods for changing loop coupling is to change the size and orientation of the loop. Loop coupling is usually placed in the high current area of the wavemeter. Capacitative coupling is changed by the size of probe and the distance from the center conductor. Capacitative coupling is usually placed at the high voltage portion of the wavemeter. As in Fig. 5, a small probe – say ½ in. piece of No. 22 wire, for example – may require an external voltage amplifier. The smaller the probe, the less effect on the resonate fre-

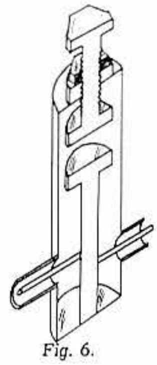


Fig. 6.

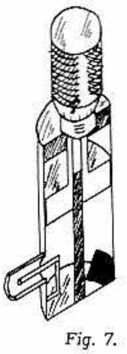


Fig. 7.

quency of the wavemeter. In direct coupling as in Fig. 6 the primary concern is impedance. To increase the impedance, move the coupling up the line away from the shorted end. To decrease the impedance, move the coupling down the line toward the shorted end. Slit coupling (Fig. 8) can be a small hole or a series of small holes or a slit. Its purpose is to allow a certain amount of leakage. In all forms of coupling, it is desirable to use loose coupling, as the wavemeter will have less effect on the system, and the Q of the circuit will be higher.

Above 3000 MHz, usually only the tunable wavemeter is used. The cavity is one quarter wave length long. The cavity can be coupled in three ways: loop, probe and slit. Because of the high frequencies, the slit is usually used, and the meter is most often

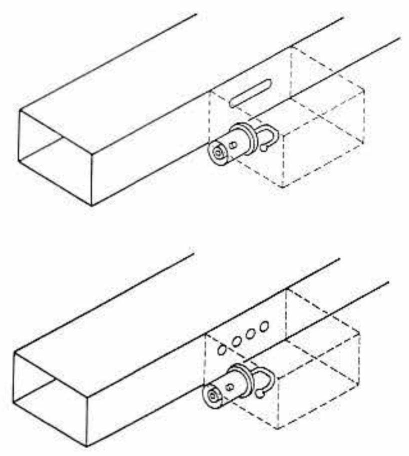


Fig. 8.

kept as an assorption meter. In the assorption method, the wavemeter should be detuned when not in use. Some of the cavity wavemeters have a little lossy material added to absorb some of the energy, as in Fig. 7. Lossy material can be made from graphite impregnated cloth in epoxy.

There is one other type of wavemeter that can be briefly mentioned; it is the reference wavemeter. The reference wavemeter is of any design as described, but would be constructed more like Fig. 6. It can be locked when adjusted to a selected frequency and used as a reference standard. The micrometer assemblies can be made from any micrometer with additional parts welded on. I constructed one using an oversized tube over the main cavity, and dimpled it at various places around its circumference until it fit smoothly over the cavity, and I used a piece of 3/8 threaded brass pipe as the main adjusting screw. I am sure you can come up with a good one without any backlash. This wavemeter spread the 1250 MHz band out to over 100 inches by rough measurements. I haven't calibrated it, so I can't say for sure just how far. There are three nice veeder root counters in the APX 6 which would make excellent wavemeters plus sliding contact material. One could even use the entire cavity.

The last method of microwave measurement that we will look at is the slotted line

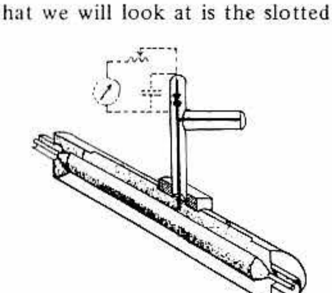


Fig. 9

(Fig. 9). The slotted line is a section of coax line along which is cut a slot. A probe, which is a simple crystal detector with a one quarter wave length shorted stub for a dc return path, is moved along near the center conductor of the slotted section. In this case we are looking for two successive minimum readings along the line. The distance between these readings is one half wave length. A slotted line should also be calibrated. If calibrated at one spot near the intended frequency to be measured, a chart will not have to be made – just a K factor obtained. The distance between two successive readings times the K factor should equal the frequency half wave length. There are a few accessories that can be either built in or used

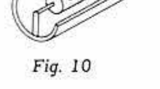


Fig. 10

externally. One is a coax attenuator shown in Fig. 4. It will slide in and out of the other half. It too can be calibrated if one wishes. A 50Ω resistor can be used for an impedance match for 50Ω lines if inductive coupling is used such as in Fig. 10 and when the loop is small. The line stretcher (Fig. 11) is useful with the slotted line. It merely consists of two coax sections, one sliding into the other.

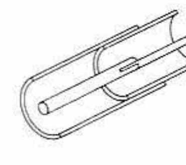


Fig. 11.

FREQUENCY METER – 1 to 10 GHz AMATEUR MICROWAVE

Bill Hoisington K1CLL

A quarter wave coaxial cavity is used up to about 5 ghz, and from there to over 10 ghz the three quarter mode is used. A complete explanation of these types of operation is given.

The same type of unit can be used as a very good tuned mixer from 1 to 10 ghz.

The Coaxial Cavity

The basic circuit of the coaxial cavity is shown in Fig. 1. A cylindrical outer cavity wall encloses a round rod some 4 inches long which is the center conductor–this center conductor is grounded at one end.

The Shape of the Cavity

The exterior shape of the cavity is shown in Fig.2. and is seen to be rectangular in cross section, with two thin walls and two thick side walls. Believe me, this configuration was not arrived at in one day! De-

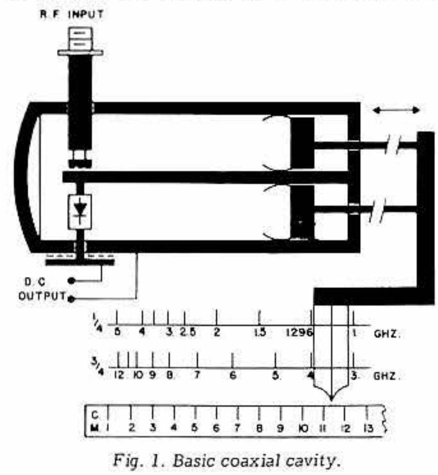
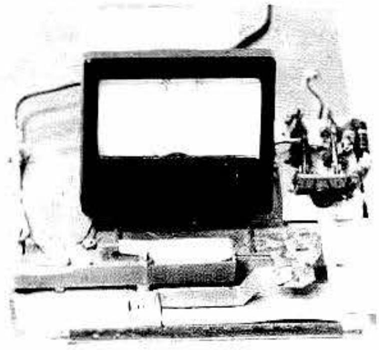


Fig. 1. Basic coaxial cavity.



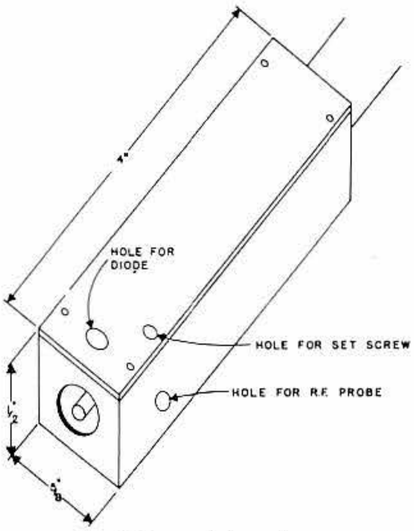


Fig. 2. Shape of the cavity.

signing tuners for X Band, I gaily started in with sections of thin-wall round pipe, the way I'd always done on uhf. The first thing you run up against is, how do you make the diode bypass capacitor? Machine out a curved saddle piece to fit exactly over the outer wall? Possible, but too expensive. And then how do you introduce the rf probe coupling into the cavity? Add on a "saddle" with a hole in it? These considerations and others, such as mounting (more saddles?) led to the abandonment of the pipe as a shape for microwave cavities; but not until a lot of time had been spent on the above mentioned items.

Diode holder and capacity

Looking at **Fig. 3.** you will see the first answer arrived at; but only after weeks and weeks of making different types and shapes. The center conductor is slightly flattened and drilled out to fit the diode prong. An 8/32 copper machine screw is drilled out to fit the other prong, then slotted with a fine

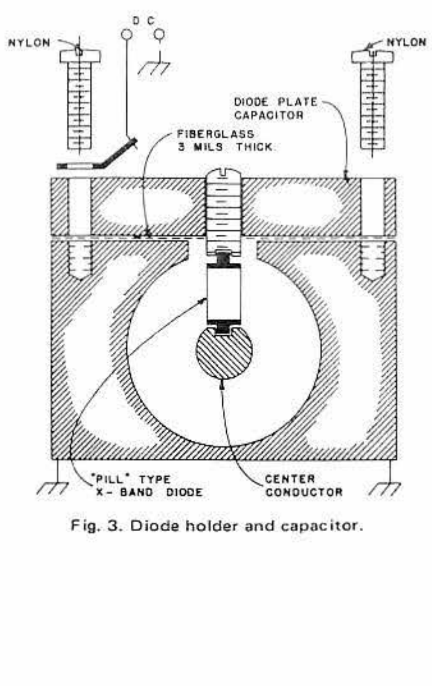


Fig. 3. Diode holder and capacitor.

jeweller's saw, and then compressed slightly to an inside diameter a shade less than the OD of the diode prong. In this way the copper screw will hold the diode as you insert it into the cavity. Believe me, that helps!

The second answer is also evident from **Fig. 3.** as the diode bypass capacity can now be made efficient at X-Band. As mentioned before, you cannot "buy" a capacitor "good for X-Band. You can make it though, as shown in **Fig. 3.**, if the cavity body has been designed correctly for it. One of the thin wall sides of the cavity is drilled out (or machined out) just wide enough to clear the diode and it's holder, which is the 8/32 copper screw. The copper capacitor plate, which is thick enough to take at least a half dozen 2/56 threads, is drilled and tapped for the 8/32 screw, and clearance drilled in the corners for the 2/56 mounting screws. A soldering lug for the dc connection is used under one of these, and a three mil (three thousandth of an inch) thick sheet of fiberglass cut out to fit, larger than the plate. This helps to keep metal particles from lodging inside the tiny crack that might be there if the fiberglass sheet did not extend out beyond the plate all the way around. You can begin to see some of the detail needed at X-Band.

Further reasons for the rectangular cross-section now show up in **Fig. 4.**, which details the rf probe connections. This item was also very troublesome in first models using pipe

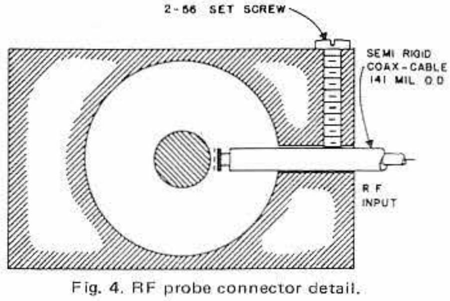


Fig. 4. RF probe connector detail.

walls, where "more saddles" was the only solution. All "saddles" are eliminated by the rectangular shape. Small semi-rigid cable is used for the connector. I have some short lengths with X-Band antennas connected to them for use as "In-Space" pick-ups, feeding directly into the wavemeter cavity. There is at times an advantage in this type of "energy collection" (antennas) which will be taken up later.

Fig. 5. shows detail of the treatment of the cavity end of the rf cable, or probe. The outer conductor is cut away for about one quarter inch in length and removed. About a sixteenth or so of the Teflon is left, which is then removed from the center conductor. A

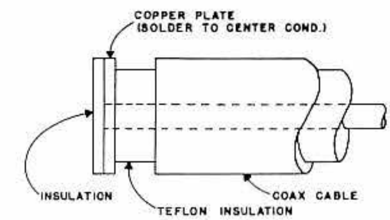


Fig. 5. RF probe detail.

thin copper washer (which I generally cut out of sheet copper since the hole to solder the center conductor is quite small) is then soldered to the center conductor, making the "capacity probe", as shown in **Fig. 5.**

Mylar tape or other good insulation is fastened to the side of this washer facing the center conductor. With this insulation in place you can push the probe all the way in, while testing, and still not have a dead short. Different thicknesses of fiberglass sheet can also be cemented on, to make up more permanent types of fixed capacitors, of different values.

For some uses, particularly in this one as a wavemeter, loose coupling is desired, but it must be securely locked with the set screw, otherwise your dial calibration and frequency reading will suffer.

Plunger fingers

Here is the most difficult item. It is hoped to have stock pieces made up for this work that you can purchase at reasonable cost. The fingers should be made of tempered beryllium-copper, which is not easy to work with.

Fig. 6. shows some details of the plunger and fingers. I assume, having been told so by "well-informed sources" (mechanical engineers) that these units should be made in a machine shop by competent machinists. Maybe so, as the ones I have made here in the shack by hand tend to lose their tension if not handled carefully.

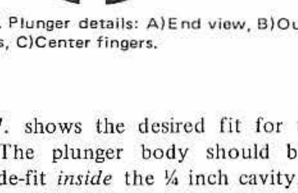


Fig. 6. Plunger details: A)End view, B)Outer fingers, C)Center fingers.

Fig. 7. shows the desired fit for these fingers. The plunger body should be an easily slide-fit *inside* the ¼ inch cavity, and the center hole in the plunger after the fingers should also be an easy fit *over* the center conductor.

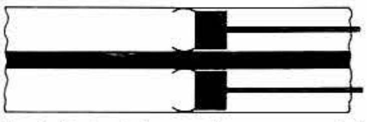


Fig. 7. Desired shape and curvature of the plunger fingers.

Two steel push rods lead back from the plunger through small holes in the back end of the cavity (see **Fig. 1.**); these terminate in the brass block which is furnished with a pointer for the frequency scale. Maximum extension of the plunger should be up against the end piece, as a positive reference point for the dial, in case of trouble after calibration. This point should be indicated on the scale as "minimum frequency" in order to reset the pointer if it should ever become displaced after calibration.

The diode

At present, the diode used is an X-Band "pill package," with a prong at each end as shown in **Fig. 3.** These are point-contact diodes, like the famous 1N23 ceramic cartridge types of World War II fame, only a lot smaller. Referring again to **Fig. 3.** always make sure that the ceramic part of the diode is, as nearly as possible, in the open space between the inner and outer conductors. This space is where the rf is! It is also important to make sure that there is as much metal surface continuity as possible along the cavity wall, across the fiberglass sheet X-Band capacitor insulation onto the diode capacitor plate, and from there over to the diode holder and onto the metal end of the diode.

The rf is at a maximum between the inner and outer conductors, which is an air space of a sixteenth of an inch. and that is where the diode should be.

The diode rf bypass capacitor, formed by the diode plate and the flat top of the cavity body, need only have a capacity which is relatively small; anything over about 20 pF is sufficient. What it *must* have is the proper *lack* of inductance! The details of how this act has been covered in previous paragraphs, and if you follow those details you will find little or no rf on the *outside* of the diode capacity plate or the dc lead from it.

X-Band is not just short waves. It is really short; like a quarter wave at X-Band equals 9/32 of an inch as you can plainly see, if you get one (or more) of those little plastic millimeter rulers in a stationery store for 5 or 10¢. Be sure and get some, by the way, if you're going to do anything above two meters.

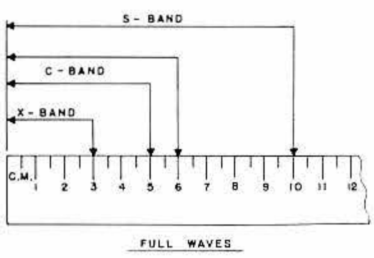


Fig. 8. Full waves for S, C and X-Bands on millimeter scale.

Fig. 8. shows the millimeter scale, with s, C, and X-Band plainly showing.

A handy wavelength-frequency chart is included here for your convenience, which is useful from the khz range way up *above* X-Band. See **Fig. 9.** Get to know the easy reciprocals, like 1 centimeter equals 30,000 mhz, 3 centimeters equals X-Band, 10 centimeters equals S-Band (3,000 mhz), 1,000 mhz equals 30 centimeters, etc. Very useful!

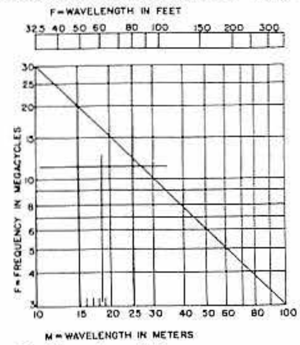


Fig. 9. Wave-length/frequency converter. Use of multiplying factors such as those at the bottom of the graph will cover any portion of the electromagnetic-wave spectrum.

The 3/4 mode and harmonics

Don't worry about that word "mode." Generally when something odd takes place in a cavity or waveguide, certain types of engineers tend to fall back on obscurantism (I seem to have fallen for that $64 word. It just means covering up). They say, "It jumped mode", or, "Spurious showed up."

Here's the straight dope. **Fig. 10** shows the quarter wave "mode" of operation. Starting at 1 ghz you will find *one* point of maximum dc output. If the oscillator under measurement is "running hard" with lots of 2nd and 3rd harmonic energy content, these will be found at 2 and 3 thousand megahertz, and possibly higher ones, which should drop steadily in power as you go up. The diode itself may cause some of these if hit too hard with the rf input.

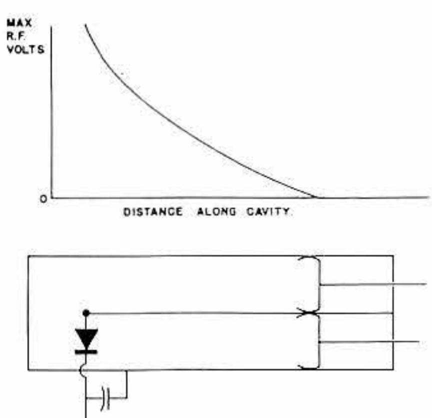


Fig. 10. Quarter wave in cavity.

Fig.11. shows the 3/4 wave mode, which is a very "natural" type of operation. Don't forget that in an instrument of this kind you are looking for standing waves and you want them to be of the greatest amplitude possible (within reason). So, if you tune the cavity by the plunger so that it measures

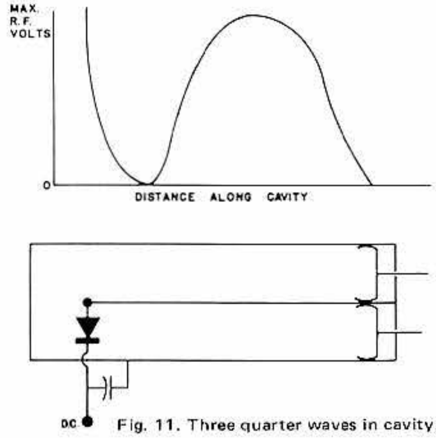


Fig. 11. Three quarter waves in cavity.

some three quarter waves on it (allowing for length-loading of the diode on the first quarter), you will find two peaks on the meter due to the situation shown in **Fig.11.** The higher the Q, and the lower the losses along the line, the more quarter waves can be found. For the 4 inch cavity shown, three quarter waves at S-Band are the longest that will fit.

A check on this operation is easy. Using the millimeter scale on the "dial", take several readings between maximums, for example, 22, 37, 51, and 67, add the spacings together, which comes to 45 millimeters, divide by three (the number of samples), and you will find an average of 15 millimeters for the waves which are standing on the center conductor (or "along the cavity", if you prefer) and there you are, 15 millimeters for the half wave, 3 centimeters for the full wave. Which is X-Band at 10,000 mhz or 10 ghz.

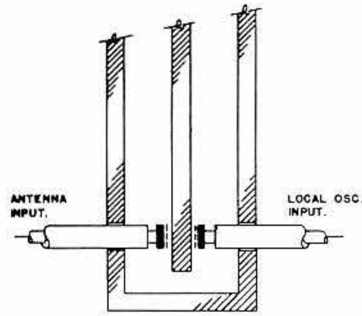


Fig. 12. Double input detail.

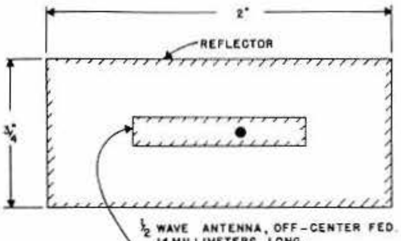


Fig. 13. Test antenna–X-Band "two-element".

If you find numbers which are not well known, you can find the frequency on the chart, at least close enough to put you in one of the microwave amateur bands, such as 5,650 or 10,500 mhz.

Use as a Microwave Mixer

This same type of cavity can be used from 1 to 10 ghz as a mixer for the front end of a superhet receiver covering those frequencies.

This application will only be touched on briefly here as the whole receiver is detailed in another article in *73 Magazine*.

Fig. 12. shows how to do it, so you can plan on this use, and make more than one, if you wish to.

Looking at Fig. 12., you can see how useful it is to have *two* thick sides on the cavity, one for rf input and one for the local oscillator input.

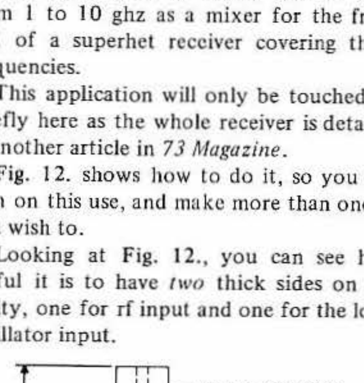


Fig. 14. Test antenna–S-Band. Dimensions suitable for amateur S-Band 2,400 mhz (omni-directional).

Conclusion

That about covers the details and some uses. The whole unit can be mounted on a piece of copper-clad, along with a 50 ma meter, the dial scale, and the centimeter-frequency chart. I broke down on this one and used a "regular" small microwave input connector for the rf. (Instead of an "RCA Phono Jack".) For connections to other units, such as oscillators and multipliers, small flexible cable may be used.

Fig. 13 shows a test antenna for X band, not the best in the world but good enough for a starter. With a lens in front it really picks up signals. Fig. 14 shows an S band antenna for the 2,400 MHz amateur frequencies.

LAMBDA LINES

James Ashe W2DXH

Over the past few years, new kinds of commercial gear and military surplus have made it quite easy to generate VHF frequencies. But the problem of measuring the frequencies has not become any easier for amateurs short on calibrated instruments. Of course this means the newcomer to VHF! What can he do to find what ballpark a circuit is radiating in, if there are no accurate devices available? When this problem came up recently, a simple solution appeared quite by accident. It was so simple, in fact, that its simplicity must be the feature that has kept it out of the ham publications. Another first for 73!

The traditional solution to the rough frequency measurement problem is to make up a Lecher Wire system. There is some question about the value of one of these in the modern ham shack. Narrow-band crystal-controlled techniques guarantee frequency and stability once the multipliers are tuned properly. In the old modulated oscillator days things were not that stable . . . so why go to all that carpentry and construction work for what fairly well promises to be a use-it-once gadget? Particularly when a little reflection (pun intended!) may bring out a cheaper, faster and better arrangement?

Ham and commercial builders of VHF gear have been using tuned stubs for years to match impedances, tune out frequencies, tune in others, etc. Yet it seems to have occurred to very few workers indeed that it might be possible to cut stubs to length accurately enough to serve as frequency standards. Apparently this can be done, with an accuracy of about 5%! This compares very favorably indeed with the performance of lower-frequency grid dip meters and some signal generators. It's pretty good for a pencil and yardstick operation: the only other items required are some understanding of how it works and a piece of 300 ohm twin lead. Belden #8235 recommended. You can calibrate that new GDO for 432 at a cost of just a few cents!

Theory

Many kinds of things show a property of tuning sharply to a certain frequency. This property is called resonance. We hear it when a struck piece of metal rings, and see it in the pendulum of an old grandfather clock. The grid dip meter shows a drop in grid current of an oscillator when a nearby resonant circuit steals energy from the oscillator. And it is the nearby resonant circuit that is the subject of this article.

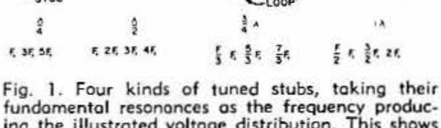


Fig. 1. Four kinds of tuned stubs, taking their fundamental resonances as the frequency producing the illustrated voltage distribution. This shows that none of them has a unique resonant frequency.

The basic circuit is the quarter-wave stub. A little browsing around in the handbooks and earlier issues of 73 and other ham magazines will tell you lots about quarter wave stubs. The important practical points are that the stub resonates at certain frequencies, and that at these frequencies it can be dipped at its shorted end in the same way as any other resonant circuit.

But the term 'quarter-wave' has to be taken with a grain of salt. The tuned stub will be shorter than a free-space quarter wave, because the dielectric has a slowing-down effect on the rate at which the RF bounces end-to-end along it. Suppose you laid out a mile or so of twin-lead and transmitted a signal, at the same time sending off a reference signal by space wave. The reference signal would arrive at the other end first, in about 5.35 microseconds. The twin-lead signal would arrive a full microsecond later, about a 20% delay. Since this applies even to short lengths of twin-lead, the delay must be taken into account for accurate measurements. Also, there is a considerable difference in velocity factors between different brands and qualities of twin-lead.

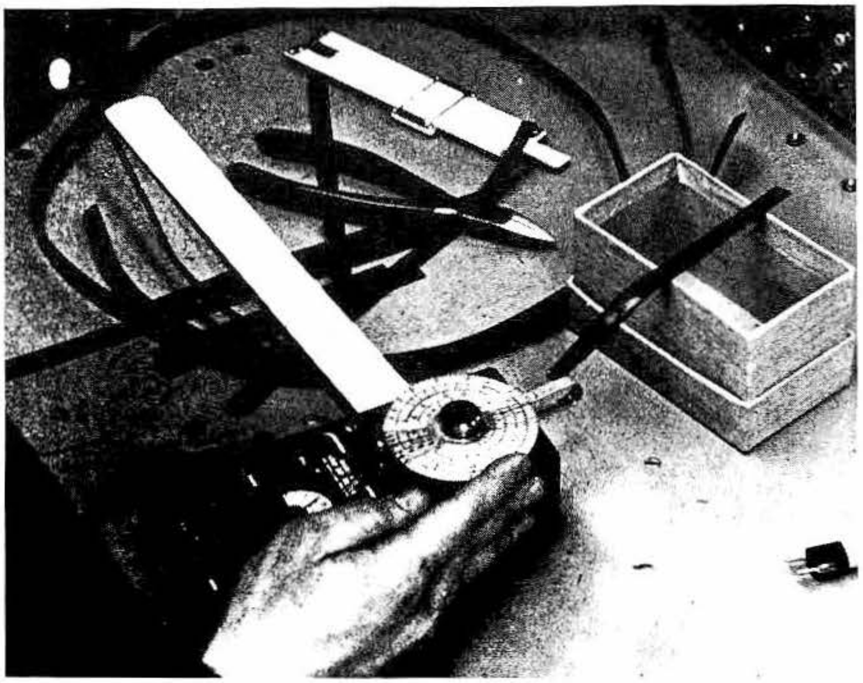
Crystals are often used in overtone oscillators for generating stable VHF frequencies. The various modes of oscillation are pictured in the handbooks. Tuned lines will also show overtone resonances, and in the case of large uncertainty, it might just happen that reasonable errors could lead to a consistent but very wrong result. A halfwave line will resonate at a frequency f, and also at 2f, 3f, and so on. Note both odd and even multiples! All other resonant lines have a similar overtone resonance property. The problem is slightly aggravated by the convenience of using relatively long lines at the higher frequencies because they are easier to handle. The solution is to cut a pair of lines whose collections of resonant frequencies have only one resonance in common. The recommended lengths are a halfwave and a three-quarter wave line.

Fig. 1 shows four basic tuned lines. Just which resonance is an overtone and which is not depends somewhat on the application. The simplest way out of this problem in semantics is to say that the three-quarter wave line really doesn't have that resonance at f/3, ignore the quarter and fullwave lines, and stick to the remaining two for test work.

At 432 MHz a wave in free space is about 27.3 inches long. Suppose we are using Belden #8235 twin lead, which Belden says has a velocity factor or propagation constant of 0.77. The twinlead wavelength than is 27.3 times 0.77 or 21 inches. The halfwave stub must be 10.5 inches long, shorted on both ends; and the three-quarter wave stub 15.75 inches long, shorted at one end. These are convenient lengths, not too long to use on the workbench, nor so short that percentage accuracy in cutting becomes a big question.

Using the stubs

The commercially available grid dip meters are not noted for accuracy. It's commonly estimated that the scale calibration can be



trusted to within about 20%. With some care, calibration points taken from twin-lead resonators appear to be good to about 5%. The first precaution is accurate construction. Cut the strips slightly long, short one end of each, and cut the three-quarter wave line to length. Then go more carefully at the other end of the halfwave line, which must be shorted at both ends. It should not be too hard to get the correct lengths within one sixteenth inch.

When making frequency checks, the lines must be held off the workbench an inch or two. Use small boxes or pieces of cardboard. Probably the better part of a foot distance is in order if the workbench is of metal or has a copper surface. At two meters, a perceptible change in calibration can be detected if the line is laid out on a wood surface! It's very good practice to make up lines for two meters or lower, and practice dipping them. Some

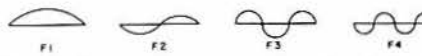


Fig. 2. Some overtone resonances of a halfwave stub (shorted at both ends). F1, F2, F3 and F4 should be 1F, 2F, 3F, 4F.

refinement of technique will certainly be required before a halfwave and a three-quarter wave line can be made to dip at the same point on a standard dip meter. Once the trick is mastered, it can be carried up to the higher frequencies.

The lines are dipped in the same way as any coil. Because they have a very high Q, there will be a tendency for the dip oscillator to pull, or to seem to give different readings when tuning down to frequency and tuning up to frequency. The remedy is less coupling: move the dip meter a little further away from the line and try again. Dip the stub at its shorted end!

But what was that trick for calibrating a dip oscillator, mentioned earlier? Can't make up a pair of lines for each frequency. No need to! That's simply the reliable way for finding the right ballpark. When you're there, you can set the lines aside, make up another three-quarter wave resonator cut for the lowest frequency, and after marking that point on the scale, trim the stub up to the next calibration frequency. Throw the remainder away when done calibrating.

The half-wave stub is also useful as a tuned coupler. Suppose you want to tune an oscillator to a particular frequency but have nothing to indicate at that frequency. Loosely couple the RF into one end of the half-wave stub, and take it out the other end with a hairpin loop, through a diode to a 50 µA meter. You will only get a reading at the resonant frequency of the half-wave stub. Simple!

Chapter V

RF Signal Generators

ZERO-BEATING WITH A FREQUENCY METER

Jim Harrison WB4TBX

After putting an LM-18 in service, I found it a nuisance to plug in headphones every time it was necessary to adjust the corrector control to produce Zero Beat at one of the crystal check points. I hooked up a phone plug to the plate winding of an audio output transformer, and then connected a small loudspeaker to the secondary winding. I leave the phone plug inserted in the LM phone jack at all times. After using this setup for a while, it occurred to me that the last few cycles either side of zero beat might not be audible, so I tried a parallel hook-up off the primary side of the transformer. The other end of the cable was connected to the Vertical input of an oscilloscope. Now, when adjusting the corrector control for zero beat, you will see low amplitude sine waves even after you can no longer hear the beat note. You tune out the sine waves until you have a perfectly straight reference line on the scope. The Heterodyne oscillator is then corrected to calibration much more accurately than trust ing to the ear alone. The principle is not new, yet the idea may not have occurred to some people. Any old scope will do, as the frequencies are in the audio range.

Another bit of frustration occurred when trying to adjust the corrector knob. I would pass the zero beat point time and time again, due to the stiffness of the control. Remember, these units are built for ship-board use, and loose controls cannot be tolerated. I dug up a small vernier tuning drive, similar to the Jackson Planetary-Vernier drive, (about 5 to 1 ratio). I mounted this drive on a right-angle aluminum bracket and attached it to the LM using the two screws on the upper right side of the unit. Bore holes slightly oversize to allow for accurate alignment of the control shaft so that it will not bind. Cut out a portion of the bracket so the "High-Low" knob can be moved. The precise Zero beat adjustment can now be made very easily with the reduction drive.

HAND CALIBRATE THE BC-221 FREQUENCY METER

Carl Henry

At present many amateurs have an opportunity that may not repeat itself. I refer to the many army and navy surplus frequency meters now available, through MARS and surplus sales. Many of these meters have the original calibration chart missing, and are considered virtually useless. This is demonstrated graphically by prices, the frequency meters with charts costing $100, the meters without charts selling for one-third this amount. Meters without charts are worth more than this would seem to indicate. It is no great job to calibrate one of these meters, but it is time consuming. A little care is required, but you do not need to be a super technician or electronic engineer to do the job. Neither is elaborate equipment required.

Essential to the calibration are several items not commonly available around the shack, but easy to build. Figure 1 illustrates the first requirement. This is a 10 kc multivibrator, which will operate from a 100 kc xtal calibrator, and give 10 kc markers up to 20 mc. I am assuming here that you have or can beg, borrow, or steal a 100 kc calibrator, this being a common item. In fact, some receivers have them built in. Using this 10 kc marker source, the high band of the frequency meter can be calibrated. Interpolation to 1 kc points is then possible, and if care is used an accuracy of better than 0.005% will result.

Fig. 2 shows a simple beat detector that can be used with earphones to get an exact zero beat. It took about ten minutes to wire up a 1629 (army surplus magic eye tube) temporarily for this purpose, and it is certainly worth while in the interest of increased accuracy.

With your equipment assembled, connect the frequency meter to its power supply. Allow at least one hour for proper warm-up so that all equipment will stabilize, including the 100 kc calibrator and 10 kc multivibrator. Set the CALIBRATE control on the frequency meter to center, and be especially careful not to move it until the calibration is complete. After the warm-up period the 100 kc calibrator should be zeroed against WWV, at as high a frequency as possible. The 10 kc multivibrator must be checked to see that it gives nine beats between each 100 kc beat. This can be done with your communications receiver, and it will be easiest to do it on as low a frequency as possible, say 600 to 700 kc. Now type several sheets of paper, listing the high range of your frequency meter by 10 kc points. If you are in doubt as to the range, check it with your receiver. To do this set the dial to the low end of its range, turn on the internal xtal, and zero in on the strongest beat at or near the low end. Turn off the internal xtal oscillator and find the signal from the frequency meter with your receiver. Note the frequency. Tune your receiver until you reach another harmonic from the frequency meter. The difference between the first and second readings is the frequency of the meter at the low end

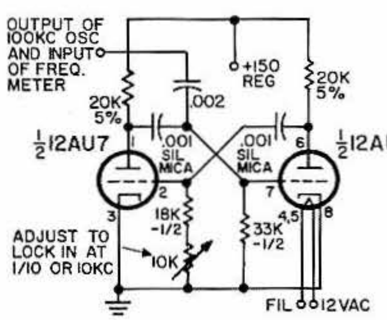


Figure 1. 10 kc multivibrator for use with 100 kc crystal oscillator, providing 10 kc beats with frequency meter.

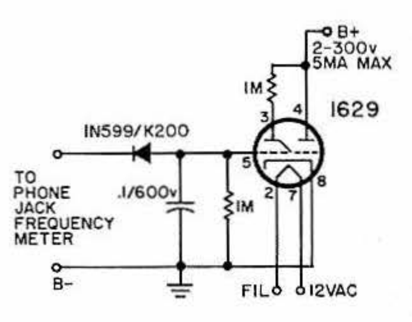


Figure 2. A simple zero-beat indicator for use in conjunction with headphones.

of its dial. Now do the same thing at the high end, and you have the primary coverage of your frequency meter. Most have a range of 125 to 250 kc on the low band and 2 to 4 mc on the high band.

When you write up the frequency range by 10 kc points, leave a space between notations, since you will be adding information here later. Now, using the 100 kc xtal, check the high band of the frequency meter at 100 kc points, listing the dial readings. Now go back and check the dial at 10 kc points, listing all the dial readings. The checks should agree with the 100 kc checks at every tenth point. This is a handy method of cross checking yourself. You might note that on equipment of this type, always approach the final reading from below. If you pass the zero beat point, don't jockey the dial back and forth for zero beat. Go back below the beat by 5 kc or so and approach again from below. This procedure will help to eliminate error from dial backlash.

After your 10 kc points are all listed, interpolate to 1 kc points. This is the hardest part of the job, and is very time consuming. A big pot of coffee and a patient and loving XYL will be a big help here. The patient XYL can be replaced with an adding machine if you have one available, but you'll still need the coffee.

The difference between each 10 kc point must be listed. Note this in the space you left on your sheets. Each 1 kc will be 10% of this, so add 10% to the 10 kc listing for 11 kc, 10% more for 12 kc, 10% more for 13 kc, and so on. When you reach the next listed 10 kc point, the calculated listing and the measured listing must agree, another cross-check. This will take 2000 individual additions.

After the high band is finished, you may wish to calibrate the low band in the same fashion. Referring to Figure 1, change the grid-plate capacitors to 0.01 mfd. This will put the multivibrator at approximately 1 kc intervals. If you have trouble syncing the multivibrator, you may have to build another to operate at 10 kc, and sync the 1 kc from this. No trouble should be had with a strong output xtal calibrator, however. Calibrate the multivibrator as before, except with 1 kc intervals instead of 10 kc.

A calibration book can be prepared when you finish. It is a good idea to file all your original calculations and papers, should the book ever be destroyed. The frequency meter is now as good as any with original calibration book, at a good saving of money.

HIGH ACCURACY VHF FREQUENCY MEASUREMENTS

Howard Burgess W5WGF

Accurate frequency measurements can be a problem for the amateur with a limited budget. However with some home construction and careful operation the average ham can make VHF frequency measurements to an accuracy better than .00015% at two meters. This is the equivalent of measuring the distance from New York to Los Angeles with an error of only 25 feet. Many commercial units cannot equal this figure. The same method can also be used for HF and UHF measurements.

There are many ways to measure frequency but few of them are satisfactory for use at the very high frequencies. The well known hetrodyne frequency meter becomes unstable when its oscillator is operated at VHF. It can no longer be held or read to any degree of accuracy. The oscillator can be operated at a low frequency and one of the harmonics used at VHF, but any error in the oscillator will be multiplied by the number of the harmonic used. A frequency meter that can be held to within 200 hertz at 4 MHz will be off by 7.4 kHz at the 148 MHz harmonic.

A second method of much greater accuracy uses low frequency crystals which are referenced to a known standard such as WWV. The harmonics of these oscillators will be quite accurate and useful far into the UHF region. However this system has its limitations. Even when used with multivibrators and harmonic amplifiers it produces only spot frequencies.

Although neither of these two methods is satisfactory when used alone, they can be combined to make an accurate and versatile system. If you haven't guessed it by now, the system works like this. A crystal oscillator operates on 5 MHz. This oscillator can be kept to zero beat with WWV with very little effort. With a simple harmonic amplifier following it, strong markers are available every 5 MHz far into the UHF region. To fill in between the 5 MHz points, and get full tuneable coverage, all that is required is to add the output of a stable low frequency VFO to the proper marker. Example: To measure 146.25 MHz just add 1.25 MHz from a calibrated tuneable oscillator to the 145 MHz harmonic of the crystal. The same results can be had by using the 150 MHz marker and substracting 3.75 MHz.

The tuneable low frequency oscillator of this hetrodyne system can be any stable, calibrated, oscillator that will give the desired frequencies. A good signal generator can be used but better yet is the old faithful BC-221 frequency meter. The crystal oscillator that supplies the 5 MHz markers should be designed for high stability. However, even simple crystal-controlled units can be kept zero beat with WWV for periods long enough to make most measurements.

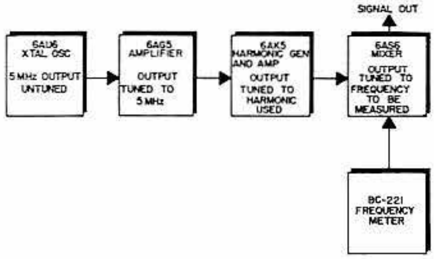


Fig. 1. Block diagram of the VHF frequency meter.

Earlier we quoted a figure of .00015% or better for the accuracy of this system. Perhaps we should show how this is possible. The crystal oscillator can be held to near zero beat with WWV but due to propagation errors in the signal of WWV, we can never be sure that our crystal is closer than 2 parts in 10 million. This would be 2 hertz of error at 10 MHz or an uncertainty of 29 Hz in the 145 MHz marker. The BC-221 is normally considered to be a .05% instrument. This would be an error of about 1.75 kHz at 3.5 MHz. However with care in calibration, and reading it is not difficult to reduce this value to 200 hertz or less. In a hetrodyne system the error of the VFO is not multiplied at VHF but is just added to the error of the crystal marker used.

The total error at 2 meters is 29 Hz contributed by the crystal and 200 Hz by the VFO for a total of 229 Hz. This is a little more than 1.5 hertz per million hertz for a tuneable system. Of course these values are approximate and with careful operation they can be reduced by 50% or more.

In the 146.25 MHz example used earlier, the VFO was required to furnish less than 1% of the total output. To put it another way, the only wobble is in the smallest cog and its contribution is so small it can't shake up the machinery too much.

The circuit shown in **Figs. 1 and 2** has been used for monitoring MARS, CAP, and several other services. The crystal oscillator is quite stable but can be tuned enough to zero with WWV. Tuning is done with C1. One stage of harmonic amplification is sufficient to give strong signals well above 150 MHz. The plate circuit of this amplifier stage is tuned to the harmonic to be used. This feeds one input

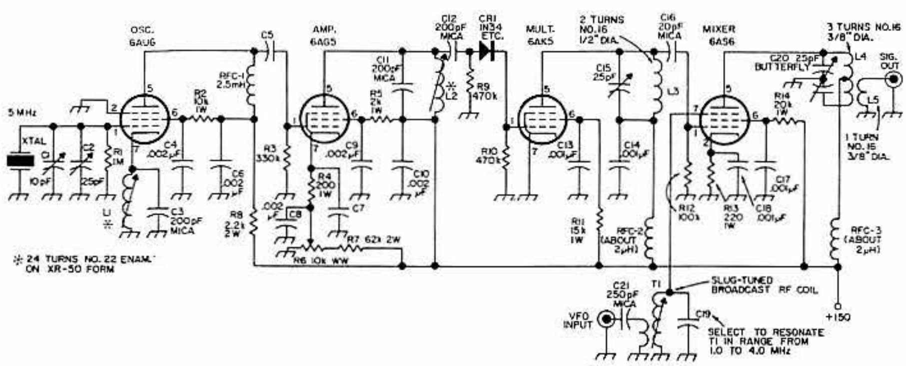


Fig. 2. Schematic of the oscillator, multipliers and mixer for using a BC-221 on the VHF ham bands.

grid of the mixer. The other grid of the mixer is driven by the output of the BC-221 frequency meter. The tuned circuit shown in this grid resonates broadly in the 2-4 MHz range of the BC-221. This helps to keep the higher harmonics of the BC-221 out of the mixer.

The output of the mixer is resonated to the desired operating frequency. This will be either the sum or difference of the two input signals. The level of the output signal can be controlled by R6.

Operation of this system is simple. The "cook book" would read as follows:

1. Couple the output to the antenna of the VHF receiver.
2. Determine the crystal harmonic and VFO frequency that will give the frequency of the signal to be checked.
3. Tune the VHF receiver to the signal to be checked.
4. Tune the BC-221 until the output of the frequency monitor zero beats the received signal.
5. If required, peak the tuned circuits in the monitor for maximum output and adjust R6 as needed.
6. The frequency of the received signal will be the crystal harmonic plus (or minus) the reading of the BC-221.

Many details cannot be covered in one story due to lack of space. The operator will have to determine the most effeceive method of coupling to this particular receiver. He will also have to explore the many combinations of frequencies which can be used. These and many other questions cannot be included at this time. However those who require such a system as this will probably be capable of filling these details.

One word of caution is in order. With two oscillators that are rich in harmonics, there can be many unwanted "birdies." These present no problem after the operator has gained experience but the new user should be very cautious. Many times an unwanted beat can be eliminated at a critical spot by changing the two frequencies that are being mixed (shift from sum to difference).

Perhaps we should emphasize that this system is a "trade off" where the amateur can trade his skill and patience for highly accurate measurements with simple equipment.

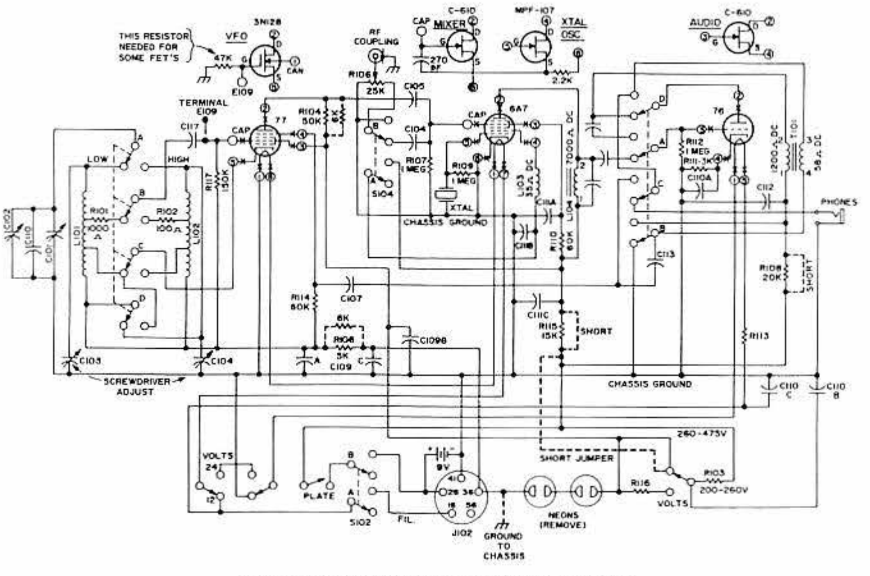


Fig. 1. Modified schematic of frequency meter.

A TRANSISTORIZED LM METER

Charles Landahl W5SOT

The last word may never be written about the BC-221 and LM frequency meters. The LM is particularly attractive because it is in the smaller package. With transistors replacing tubes, it has features most everyone wants – it is rugged, portable, and accurate, to name a few. I will describe a conversion of an LM-15 frequency meter in which field-effect transistors replace tubes; the power supply becomes a standard 9V transistor radio battery and the current drain is less than 3 mA when all functions are energized. In addition, I offer calibration information which will be of interest to anyone having a BC-221 or LM without the official calibration book. I bought an LM-15 for a temptingly low price (Fair Radio Sales Co., Lima, Ohio, $14.95). The set is sold in the "as is" condition with tubes and crystal but without calibration book. It is a good idea, but not necessary, to start with a set which is working before making the change to FETs. Resistance measurements will show if the circuits are complete. Important values are marked on the schematic of Fig. 1.

Smash Tubes

The most difficult part of my conversion was getting up the courage to smash the tubes! I wanted the bases for mounting transistors. Place the tubes one at a time in a paper sack, hold the top closed and with a metal object, strike the glass through the paper. The flying glass is caught and collected for disposal. Scrape and clean the mastic from the inside of the tube bases. Should you choose to mount a transistor socket in the wall of each tube socket, you can use the original wires; otherwise, unsolder the old wires and replace the needed ones with about 2 in. of sturdy new tinned wires. The appropriate tube base pin connections are shown in Fig. 2. Actually there is no preferred mounting scheme. Use whatever appeals to you.

Check for clearance between socket and walls. My conversion used transistor sockets mounted on metal plates which were bolted to the wall of the salvaged tube bases. This allowed FET substitution to determine which ones would work best in the several circuits of the LM. All FETs used are N-channel.

Modification

With cover removed and the LM in the upright position, front panel toward you, on the left side wall, look through two oblong machined slots and see mounted on a phenolic board a 50 kΩ plate resistor. Parallel it with about 6 kΩ. Turn the LM upside down, panel toward you. On the underside, two resistors must be shorted and a jumper wire made up and connected. Short R115, which is a 15 kΩ wirewound resistor, quite visible on a phenolic board at the left of the 1000 kHz crystal can. Run an insulated wire from a terminal of this shorted resistor to the 260–470V tap contact of the link switch. This wire can be about 6 in. long and conveniently passes through a wall slot behind the crystal socket. The link switch and its terminals are on a phenolic board in the compartment aft of the crystal socket. The jumper wire will cross near the grid resistor, R109, of the crystal oscillator. While there, change the 100 kΩ (R109) to 1 MΩ. Next, unfasten the screws holding the phenolic board located to the left of the power plug. Tip up the board and short across R108. This is a 20 kΩ composition resistor which is in the plate voltage line to the audio amplifier. Also, at the power plug, locate pin 36. Short it to chassis ground. On most sets pin 36 is the ground return for the vfo cathode. The circuit was closed through external connections in a power supply. You have completed the surprisingly few changes needed to make the LM work on FETs and a 9V battery.

The VFO

With FET source connected to pin 5, drain to pin 2, can to pin 1 (if needed), plug the FET into the vfo socket. Connect

a solid wire between terminal E109 and the gate of the FET. (Terminal E109 held the grid cap wire for the vfo tube.) Connect a 9V battery to the power plug pins. PLUS to 26 and MINUS to terminal 41. If you have a milliammeter in the battery lead, it should read about 1.5 mA when you turn on the FIL and PLATE switches. Provided you were fortunate in the choice of FET, you should hear a clear CW signal in your receiver. Set your receiver to 2 MHz or 4 MHz. You may need to connect a wire from the rf coupling post on the front of the LM to your receiver antenna. Rotate the LM dial between 0300 and 0600 on the readout. Your vfo will be on the low end of 125–250 kHz or 2–4 MHz depending on the position of the low or high band switch. The XTAL and MOD switches should be off. The FET selected for the vfo may require a 47 kΩ resistor between gate and chassis ground. I found this to be true for the RCA 3N128, 3N142,and *one* of the two 40559A FETs. On the other hand, one RCA 40559A and one of several 2N3085 silicon N-channel FET from Poly-Paks worked beautifully without adding 47 kΩ to the gate.

Apparently junction and insulated-gate field-effect transistors have slightly different characteristics which show up in this peculiar vfo circuit. My own choice is the 3N128 with the additional resistor on the gate. You may find it necessary to "tune" the source, drain, and gate resistances in order to have your vfo working well with a particular FET. I used potentiometers across the various elements to arrive at the recommended values. My vfo works reliably from 10V down to 6V and the maximum drain current is 1.5 mA.

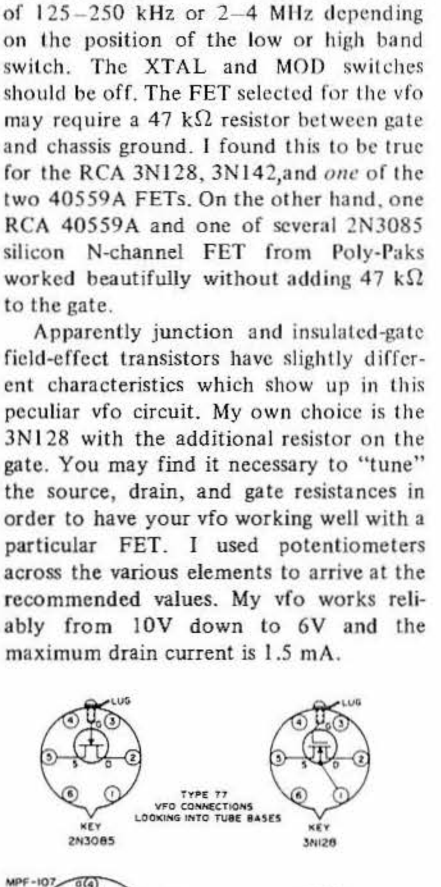


Fig. 2. Suggested semiconductor hookups for tube sockets.

Caution

Other oscillator hook-ups may occur to you, and they will work – but the tuning range and linearity of the vfo will suffer! Linear tuning is most important, so stick with that shown.

The AFO and AF Amplifier

The audio oscillator and amplifier wasn't as fussy as the vfo. I used a Radio Shack 276-664 FET – it is said to replace a C-610 or 2N3088. I found that the Poly-Paks "hobby" FET 92CU588 will work equally well. In making up the socket, gate goes to tube pin 3, source to cathode pin 4, and drain to plate pin 2. That is all there is to this one. Plug in the FET. When you next turn on the 9V power, the milliammeter will barely increase a few hundred microamps as you switch on the modulation control. At this moment a rather pleasant 500 Hz tone will appear on the vfo frequency no matter which harmonic you have tuned in on receiver. Your modulator is finished. The audio amplifier is too, for that matter. You just won't hear anything in the headphones until you complete the crystal oscillator and the mixer circuits.

Crystal Oscillator

The reference oscillator is not much trouble. You have already changed the gate resistor from 100 kΩ to 1 MΩ. Actually this change may not be necessary because some crystals are more active and will oscillate well with the original resistor. Mine went into oscillation better with the higher value. The FET you select for this circuit can be one of several. Mine is a Motorola MPF-107. I found the Radio Shack 276-112 and the Poly-Paks 2N3085 also work, but draw more current. Whichever you choose, the gate connects to base grid pin 5, source to cathode pin 6 *through* a 2.2 kΩ resistor. Drain hooks to plate pin 4.

Now, when 9V is turned on, MOD off, XTAL on, you should hear the crystal oscillator signal every 1000 kHz on your receiver. The milliammeter should increase about 1.5 mA or less when XTAL is turned on. If you don't hear the crystal frequency, bring the receiver antenna wire close to the crystal FET. We still haven't made the connection which adds the crystal-oscillator signal to the rf coupling post on the front of the LM. Assuming you have all circuits in working order up to this point, we move to the mixer.

Mixer

There is no single FET substitute for a pentagrid converter tube. The dual-gate MOSFET comes closest; however, use of one would have defeated my goal of simplest conversion. Therefore, four N-channel FETs are needed to do the work of three tubes, but what a saving in power supply! The mixer concerns itself only with beat frequencies occurring between the reference oscillator, vfo, or an external signal – all audio work. Thus, a hobby FET was selected. I used the Poly-Paks N-channel FET. A Radio Shack C-610 replacement will also work. Connect source to chassis ground through pin 6 of the tube socket; the drain connects to plate pin 2, gate to mixer grid cap wire through the lug in tube socket wall.

Finally, connect a capacitor (200–300 pF) from the top of the 2.2 kΩ crystal oscillator source resistor to the gate of the mixer FET (grid cap wire). You are in business.

With 600Ω phones plugged into the LM, you should hear all the necessary beat frequencies occurring between the vfo and the crystal oscillator as you tune the vfo through its range. XTAL must be on and the MOD switch off. Otherwise, the audio amplifier becomes the modulator and you hear nothing in the LM phones.

What Next?

With the beat notes loud and clear you are ready to calibrate. This is quite the most fun part of the work because the linear tuning rate of the LM is almost unbelievable. The slow rate is due to the series combination of the A section of C109, C101, tuning L101 or L102. The amount of the matter is that one revolution of the 100-division circular dial produces about 3 kHz change on 125–250 kHz range, and about 50 kHz per revolution on the 2–4 MHz range. The actual calibration of my unit was 2.89 kHz and 45.17 kHz per revolution.

The linearity can be checked by how little you need to vary the "corrector" for each zero-beat checkpoint. Each LM or BC-221 will be slightly different. Now, when you consider that the vernier allows you to split one division into tenths, then it is clear that you can set a frequency to better than 0.5 kHz over the range of the frequency meter. May I repeat:

1 dial revolution of
100 div = 45.17 kHz
1 division = 0.4517 kHz
1/10 div = 45 Hz

Therefore, all you need is a checkpoint at which to zero the vfo and start counting revolutions, divisions and tenths of divisions to accurately set any frequency within the two ranges of the vfo. I found it useful to construct graphs on K&E 358 11L graph paper. The grid is 10 X 10 (per 0.5 in.). The paper has 20 units vertical and 30 horizontal. This allows graphing 100 division and leaves room for 10 vernier

divisions on the right hand end of the paper. Use the crystal checkpoints listed in Table I to locate *your* dial settings. Once graphed, a frequency can be selected directly from the chart, or, depending on the accuracy desired, interpolated between checkpoints.

Table I. Crystal Checkpoints

KHz	VFO	XTAL	Approximate Dial Settings
Low Band			
125	8	1	0320
150	20	3	1192
166.667	6	1	1750
200	5	1	2935
222.222	9	2	3700
250	4	1	4647
High Band			
2000	1	2	0396
2250	4	9	0945
2500	2	5	1493
2750	4	11	1050
3000	1	3	2606
3250	4	13	3150
3500	2	7	3711
3750	4	15	4262
4000	1	4	4812

It is obvious from this discussion that the low band of the LM is fabulous. You can squeeze down to about 3 Hz by use of the vernier scale. By the way, hidden behind two cover plates just beneath the corrector knob, are "high" and "low" padder capacitors. These were used when vfo tubes were replaced to bring calibration book values into usefulness. The padders should be set near the middle of their range.

Make it Handy!

Fasten a handle to the case, strap on a 9V battery, go forth and have fun with your rejuvenated frequency meter. I use mine for its intended purposes as well as a band-edge marker and keying monitor.

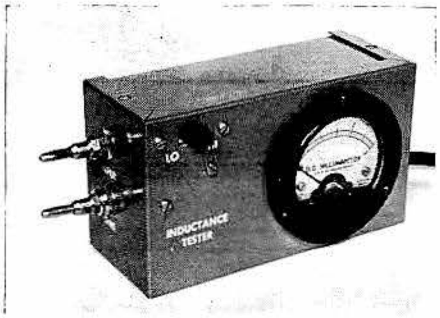
AN I-F SPOTTER

Howard Burgess W5WGF

If you have ever tried to find the *if* frequencies of unfamiliar and inoperative pieces of surplus gear with no schematic, it is a waste of time to tell you how rough it can be. Even a single *if* transformer from the junk box can be a problem if it has no part number or identification.

Of course in some cases a grid dip meter can be used to find the operating frequency. However, few grid dippers cover the important *if* frequencies below 2 mc. To complicate things, if a dipper is used on a shielded transformer above 2 mc, the resonant frequency of the transformer may be shifted if the shield is removed.

If these problems sound familiar to you, we would like to suggest a little gadget that can help solve them. With just two resistors, two capacitors, and a tube, don't expect it to give a digital read-out to all your questions, but it can put you in the ball park.



The if spotter. The switch for changing the coupling capacitor is at the upper left marked "HI" and "LO." The posts on the end are X1 and X2.

The principle of operation is as simple as the construction. The tuned circuit in question is merely made to oscillate at its resonate frequency. The frequency can then be determined by tuning in its radiated signal on the ham receiver. To set the unknown coil into oscillation requires the use of a simple "two terminal" oscillator. Such an oscillator is shown in the schematic of Fig. 1. When any tuned circuit is connected to the two points marked X, the circuit will oscillate at its resonant frequency.

In this oscillator the twin triode is a tube such as the 12AT7. The section V2 furnishes the necessary feedback and eliminates the need for extra coils or feedback connections.

The construction is simple. The unit could have been built in a larger case with its own power supply and would have become a nice piece of bench equipment. However, due to the few parts required and the small amount of plate power used (3 mils at 90 volts) it was built as an overgrown probe. The power is robbed from another piece of test equipment or the receiver.

As a probe it can be used on the work bench to test individual coils and transformers or it can be held in contact with the various transformers in a receiver.

There is only one point of caution that should be observed in construction. The lead from the grid contact of VI to the XI post should be kept as short and direct as possible with the least capacity to ground. This lead becames part of the oscillating tuned circuit and limits the upper frequency to which the unit will operate.

The coupling capacitor from the grid of V1 to the plate of V2 furnishes the feedback required to maintain oscillation. To reduce the loading on the tuned circuit, this capacitor should be held to the smallest value that will sustain oscillation. Because of the wide range over which this instrument operates, a switch is provided to change values. With the capacitors shown, operation is possible from about 60 mc down to well below 50 kc. The larger value is used at the lower frequencies and is switched in only when required. With coils of medium Q the switching point is around 3 to 5 mc.

The connectors X1 and X2 can be almost any kind of posts. The ones shown on the unit here are banana plugs. These can be used as test points, or alligator clips can be slid over them for use in clipping to coil leads.

The meter shown is a three mil meter and is used to read the total plate current of both halves of the tube. This will indicate when the circuit is oscillating. When the tester is not oscillating the meter will indicate a current of about 1 mil (with 90 plate volts). Under oscillating conditions the meter will rise to as much as 3 mils with a high Q coil. The actual amount of current is not so important as the fact that the upward shift indicates that the coil is not open and is oscillating. A 5 or 10 mil meter will serve the purpose just as well.

As the pictures show, this unit was built in a small 5" x 3" x 2" box. The unit will work just as well if it is built on a small piece of peg board with a couple of leads run out to the multimeter. This is for the man in a hurry.

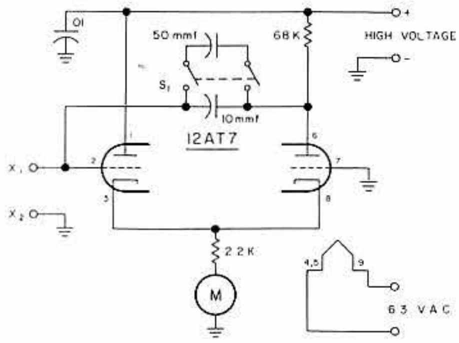


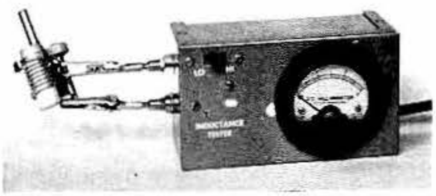
FIGURE 1

Circuit diagram of the if spotter

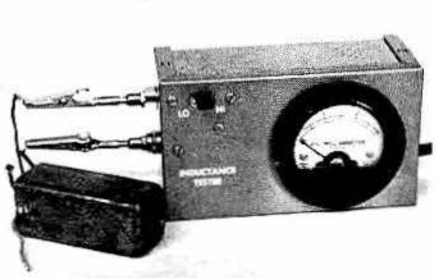
.01 Ceramic capacitor
50 pf Mica capacitor
10 pf Ceramic
68 K ½ watt carbon resistor
22 K ½ watt carbon resistor
Milliammeter in range of 3 to 10 ma
Slide action Double Pole-Single Throw switch (S1)
2 Banana plugs (x1 and x2)
12AT7 tube
Minibox (size depends on type of meter used)
9 pin miniature tube socket

When the unit is finished, apply power with the "X" points open (no coil across them). Because of the open grid of V1, the meter will drift about. After the tube has had time to warm up, short the X posts with a heavy piece of bus or copper. The meter will now come to rest somewhere around 1 mil. This is the "no oscillation" current and should be kept in mind as a reference point for future use. Now remove the short and connect almost any kind of an LC circuit across the posts. The meter reading will now rise from the "no oscillation" value indicating that the coil is oscillating. Do not use the large coupling capacitor unless the circuit refuses to oscillate with the smaller value.

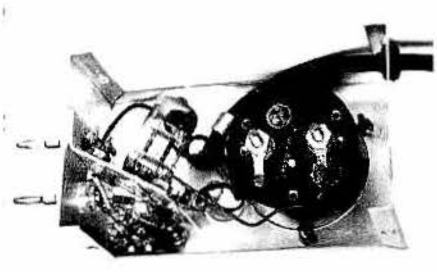
To check a single *if* transformer, all that is necessary is to hook one of the *tuned* coils



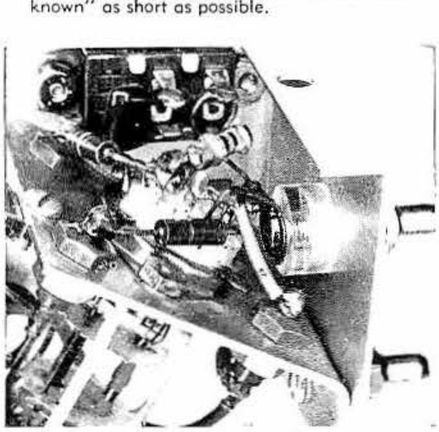
Checking a ten meter tank circuit



Checking an if transformer



Inside view showing extreme simplicity of the "Spotter." The tube is mounted at an angle to keep the grid lead to the "unknown" as short as possible.



Close up of tube socket showing parts placement.

to the input terminals of the tester. Some transformers have a number of terminals which may not go directly to the tuned circuit inside. To obtain oscillation there must be both a dc and an rf path between the two pots.

If the transformer is one whose frequency falls in the range below the broadcast band it is quite convenient to have one of the surplus receivers that covers the range down to 200 kc. However the check can still be made with a regular broadcast receiver. All that is necessary is to find the harmonics of the tester as they fall in the broadcast band. They will be separated by a value equal to the frequency of the coil being tested. As an example, if a signal is spotted at 900 kc and the next one higher is found at 135 kc, it is a pretty good bet that the transformer is operating on 450 kc ($1350 - 900 = 450$).

To find the operating frequency of an *if* stage it is not necessary to have the amplifier in operating condition or the tubes hot. Just connect the two contacts across the primary or secondary of the transformer in question and watch for signs of oscillation on the meter. Some transformers have a portion of the bias system inside of the can. This can usually be overcome by connecting the tester from grid to ground of the tube in the stage being tested.

In addition to checking transformers it can also be useful in testing the range over which a transmitter tank will tune. Just make sure that the high voltage is turned off and connect the probe across the tank to be tested. Now you can tune the tank and follow its entire usable range with the receiver. If the tank being checked happens to be the final, the meter on the probe will indicate when the antenna is brought into resonance.

This little tester was built to do just one thing—sort out some old *ifs* in the junk box. After we tried it we found that it would do a lot of useful chores around the ham shack. With proper care and feeding, it can probably learn to do tricks that we haven't even thought of.

430-470 kHz SWEEP FREQUENCY GENERATOR

Edward Lawrence WA5SWD

Here is a simple sweep frequency generator for aligning the most common *if* strips. The unit has only one transistor because the sweep voltage is taken from the oscilloscope it is used with. Most general purpose oscilloscopes have a sawtooth output jack. By using this sawtooth, the frequency is locked to the position of the trace.

The oscillator is made to deviate in frequency in step with the voltage applied to the base bias circuit, either the sweep voltage or the dc voltage applied at the control point. If no sweep or control voltage is applied, the oscillator runs at the center frequency, and may be used as a conventional signal generator.

The 2.5 mh choke and the two 150 pf capacitors form a very broad tank circuit, so it is easy to FM the oscillator without a great change in amplitude. As to how the change in base voltage causes the frequency shift, I am not quite sure. All I know is that it is quite linear and is a positive shift (**Fig. 3**). That is, an increase in base voltage causes an increase in frequency. Also, a change in collector supply voltage will shift the frequency, so be sure to use a stable supply.

Since an rfc is used as part of the tank, you may have to compensate for a variation in center frequency by changing the 150 pf capacitors to some other value to get 455 khz as your center value.

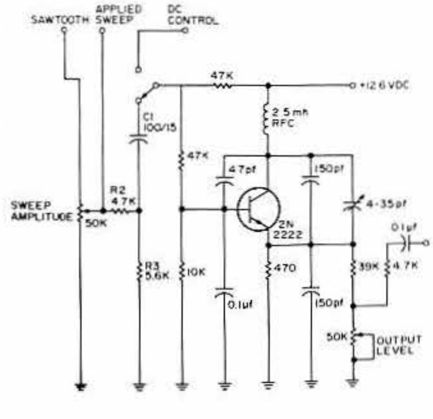


Fig. 1. Sweep generator circuit diagram.

If you do, then run a plot of dc control voltage vs frequency and adjust the voltage divider R2 and R3 so that 1 volt P-P at the sweep pot wiper gives plus and minus 5 khz (10 khz total). This is not as hard as it sounds. Just listen for the harmonics on a broadcast band radio. For instance, the second harmonic of 430 khz is 860 khz, and the second harmonic of 470 khz is 940 khz, both handy on the BC radio. Note the dc voltages at the control point required to obtain these frequencies. Take the difference and divide by four. The answer is the P-P voltage required to shift the oscillator plus and minus 5 khz. Then apply a low, known ac voltage to the wiper of the sweep pot with the switch in the *sweep applied* position. Adjust the value of the divider resistors to get the proper fraction. In my case it was 0.43.

It is advisable to run the sweep rate as slowly as possible, in order to display the response curve as accurately as possible. The sharper the skirts, the more slowly the generator must pass through the bandpass. With this generator, the amount of frequency deviation is controlled by the P-P amplitude at the sweep pot arm. If you are looking at the response of a regular *if*, you would set the sweep amplitude high to see the entire response curve. As far as an accurate display is concerned, this is fine, since the slope of the skirts is shallow. But if you were looking at the response of a sharp filter, you could not tolerate such a wide sweep, because the fast rate-of-change would tend to skew the display. To correct this, reduce the sweep amplitude to reduce the frequency deviation down to the edges of the skirts of the response curve. This reduces the rate of change and minimizes the skewing of the display. Also, it is better to display the *if* before detection, if possible, to prevent the detector time constant from possibly distorting the display.

If you have the sweep generator set up as described, then it is easy to set the sweep for a known deviation, and then procede to read the 3 or 6 db points from the face of the scope. Be sure to disable the AGC for this test.

For those who aren't familiar with the setup for obtaining the response curve display, refer to **Fig. 2.** and the following outline.

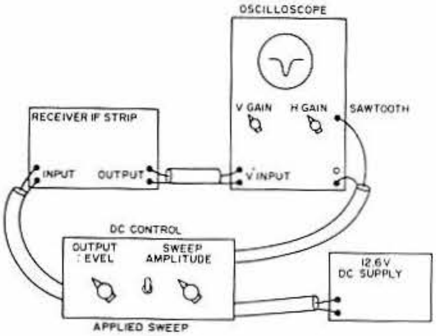


Fig.2. Interconnections of sweep generator.

First, hook up the equipment as in Fig. 1 Set *horz gain* for desired sweep width. Adjust *sweep amplitude* pot on generator for desired frequency range. Set *output level* to mid-range. Adjust the *vert gain* for the desired pattern height.

If we wish to change the total frequency deviation and the horizontal display width at the same time, use the scope's *horz gain* control. This presumes that the amplitude of the sawtooth output is also varied by the *horz gain* control.

If we wish to change the frequency spread and not change the width of the scope display, adjust the *sweep amplitude* control. This allows you to take a better look at the sidelobes or any ripples in the passband, depending on how the controls are adjusted.

You don't have to use a sawtooth to sweep with if it isn't handy.

Sixty hz can also be used, but it will probably skew the passband you are trying to display, so I don't recommend it. One note here: when the sweep generator is first turned on, or the setting of the sweep amplitude is changed, the frequency will drift for a few seconds. This is due to the charge on C1 changing to a new level. C1 is large to couple the low frequency sweep with as little distortion as possible.

Fig.3. Sweep frequency vs dc voltage.

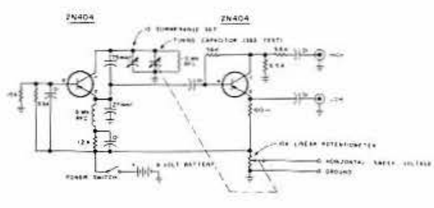
DC CONTROL VOLTS	FREQUENCY
5.86	430
6.27	440
6.69	450
6.90	455
7.12	460
7.33	465
7.55	470

AN ARMSTRONG SWEEPER

Al Donkin W2EMF

Sometime ago while experimenting with SSB crystal filters at 480 kc, it occurred to me that a manually swept Armstrong oscillator with a pot coupled to the tuning capacitor for 'scope sweep voltage would save point by point frequency measurements with a BC221 while adjusting the filter for minimum in-band ripple. A circuit was hurriedly developed, and the results were even better than expected. Simple though it may be, I'm sure anyone who is working with crystal filters will appreciate its usefulness. The effects of tuning and "diddling" were immediately visible in the in-band ripple and the skirts down to about 20 db could be observed with a few twists of the knob.

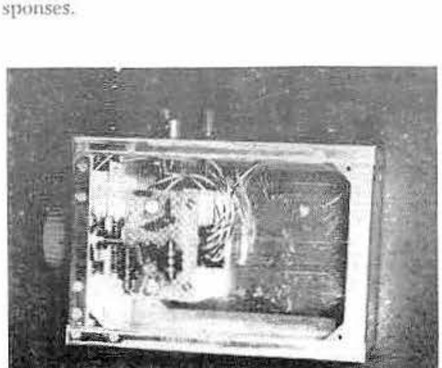
With this encouraging experience, a sturdier



model was constructed. The circuit was assembled on a small piece of Vector-board, with the tuning capacitor and batteries mounted in a $5 \times 7 \times 3''$ aluminum chassis. An aluminum bracket was bent to hold the "sweep" pot and mounted behind the tuning capacitor, spaced to accomodate the mechanical shaft coupling. The Vectorboard was also mounted on the bracket.

The oscillator circuit is simple, using a 1 mh rfc for the tank inductor. The range of the circuit as shown is about 400 kc to 500 kc, at center frequency. The tuning capacitor is a Hammerlund MC-50-M with two of the rotor plates removed, resulting in a range of approximately 7-25 mmfd. An untuned amplifier provides isolation of the oscillator from the reactance of the load. I used 2N404 transistors but most PNP *if* transistors will work.

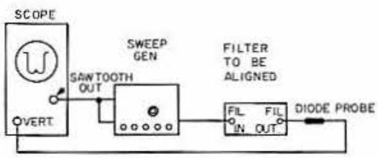
In addition to sweeping crystal filters, I have found this little box handy as a general purpose low frequency oscillator and sweeper for receiver *if's*. The persistency of most oscilloscopes produces a much better display than might be expected, and it certainly beats the point by point method of plotting filter responses.



A NEW BROOM

Dick Gridley K6JHJ

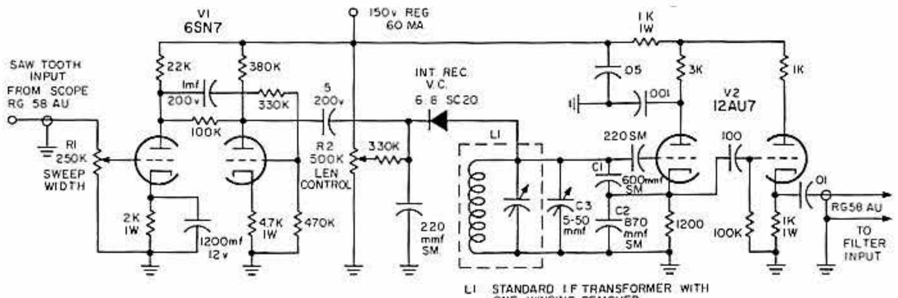
This unit is a sweep generator of simple design, with many uses. Besides being useful for filter alignment, as shown in the diagram, it is useful for optimizing receiver and transmitter performance.



The heart of the rig is an inexpensive item called the Vari-Cap by International Rectifier Corp. Two are discussed here, the 6.8SC20 and the 100SC2. The 6.8SC20, according to the manufacturer, will vary its capacitance from 50 mmfd at .lv to 2.5 mmfd at -200v. The 100SC2 will vary from 600 mmfd at .lv to 100 mmfd at -10v. These units each cost less than $3.00. The construction is not critical in any way, nor is layout a problem—just use good ham practices. Any power supply delivering 150 v dc at 60 ma regulated will do. The oscillator tank must be grounded and I did have some trouble until I removed the unused winding from the 455 *if* transformer used for the oscillator tank.

Sawtooth energy is applied to R1 which regulates the amount to be amplified by V1. R2 linear control merely puts a portion of regulated voltage on the Vari-Cap and thus sets the capacity of Vari-Cap close to its center, so the sawtooth pulse creates a linear frequency swing. This circuit gives about 6 kc sweep. I have used TV horizontal coils for L1 and increased C1 and C2 to .003 for 85 kc and 50 kc operation. However, to get enough swing at low frequency, the Vari-Cap was changed to a 100 SC2. For 200 kc to 10 mc the 6.8SC20 gives plenty of sweep.

A note here about scopes. Most of the average do not go below 15 cycles and the sweep rate should be about 10 cycles. Some do not have a sawtooth output jack. The sawtooth output can be picked off the sync circuit. I found the best point is on the feed side of the sync pot through a .25 mfd capacitor. Some scopes have a couple of jack pins to add capacity externally, some don't. You will find little trouble adding about .25 mfd across the slowest speed.

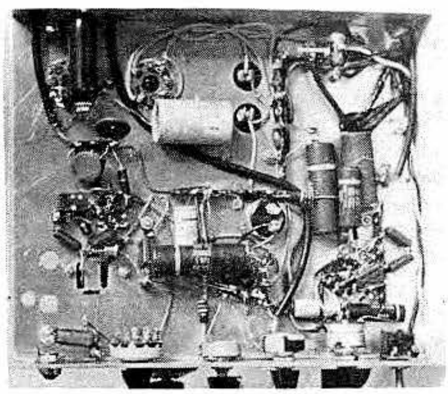


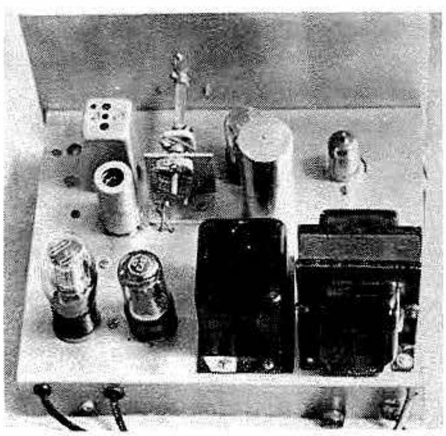
L1 STANDARD I F TRANSFORMER WITH ONE WINDING REMOVED
SM- INDICATES SILVER MICA.

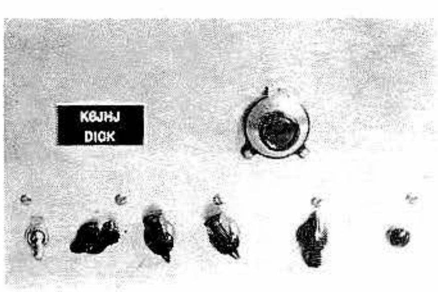
The use of the rig is simple. Plug the lead from R1 into the scope's sawtooth output. Couple the output from the cathode follower section of V2 to the filter input through a .001 mfd capacitor. The vertical input of the scope is connected to the filter output through an rf probe. Adjust R1 and R2 about ½ open. With C3 about ½ meshed, adjust the trimmer in the *if* can to put you in the ball park, and then use C3 for fine adjustments of frequency. Additional minor adjustments of R1 and R2 may be necessary. Of course, when used to align a receiver, the diode probe is unnecessary if the input to the scope is picked off of the diode detector. It goes without saying that it is necessary to plot an index for the scope bezel so that a ready reference is available for band pass width and depth of skirt.

Some one now says "This is just like setting ye old TV—*if* band pass." That it is. The only difference here is the frequency and the sweep generator cost was junk and $5.00.

The unused switch, shown in the photo, was installed to select one of three frequencies. However, this rig has been used on about six. I don't think I ever will decide which three to use. The unidentified tube is a 6U8 used as a 1 kc audio oscillator with cathode follower output.







LOW COST SIGNAL SOURCE

Howard White VE3GFW

For many years the Measurements Corporation Model 80 signalgenerator has been the industry standard for tuning rigs. Many hams have wanted to have a laboratory-grade signal source of this type but the $800 price tag is prohibitive. This article describes a signal source that has many of the same features as the 80 except that it only costs 1% as much. That's why I call this the Model 0.8.

You wonder at some of the features of the marvelous little device? To briefly list them, it has:

- Variable output from about 80 nV to 50 mV of rf power.
- Frequency range from 1.8 to 450 MHz so you can cover 160 through ¾ meters.
- Crystal-control frequency stability.
- Fairly clean output signal.
- A 51Ω antenna load.
- Safety feature to prevent the destruction of the device in case a transmitter is accidentally loaded into it.

The Circuit

The circuit is the combined brainchild of many ham engineers and technicians in our local 2m FM club – the Toronto FM Communications Association. More than 300 of these units have been built in the past two years, so the circuit has been exceptionally well tested in the field.

The unit consists of a single 2N5130 NPN transistor oscillator configuration. Other transistors, such as the 2N706, can be used in this circuit with slightly different biasing arrangements; however, the 2N5130 appeared to give the cleanest output signal.

Output level can be varied from less than 80 nV (the best we could measure) to 50 mV. It is controlled by a 1 kΩ pot in the transistor collector circuit. Power is obtained from a 1.5V penlight cell bypassed for rf by a 0.1 μF capacitor.

My present "0.8" signal source has been used intermittently for more than a year without any degradation of output. However, remember to shut the unit off when you're finished with it; the battery doesn't last forever.

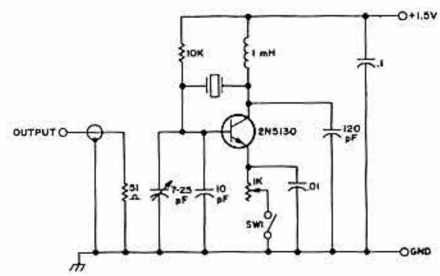


Fig. 1. Schematic diagram of the "Point Eight" Signal Source, the "poor man's Model 80."

The unit is built on a PC board. The parts layout is almost exactly the same as that of the schematic shown in Fig. 1. The electronic components are placed on the copper side of the board. The on-off switch-level control, frequency adjustment, output jack, and crystal socket are on the other side (Fig. 2). The unit can be packaged in a minibox.

Almost any crystal in the 1.8 – 12 MHz will oscillate in this unit. The output is rich in harmonics to 450 MHz, so you can tune up any receiver from 160 to ¾ meters.

The output impedance of the signal source is 51Ω, a value which simulates a perfect antenna load to the receiver. This is the manner in which this is accomplished: A 51Ω, ½W resistor is connected across the terminals of an RCA phono jack. No physical connection is made to the circuit except through the common

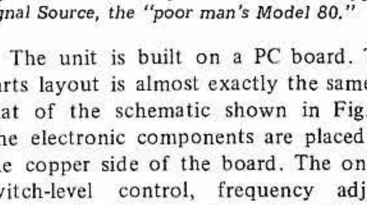


Fig. 2. Minibox layout of the signal source panel.

ground of the PC board. The maximum output level depends on the lead lengths of the resistor. (The unit has plenty of output when the lengths are about ½ in. long.) This design has an added safety feature, too; if by accident you load a transmitter into the unit, all that is destroyed is the ½W resistor.

Operation and Uses

These units were originally designed to tune up 2m FM receivers. The procedure is quite simple. You connect the signal source to the antenna input on your receiver. Plug in a transmit crystal, and adjust the frequency control for a zero reading on the discriminator. Adjust the output level to the desired signal strength (below first limiter saturation) and tune up the receiver.

There are a myriad of other uses for the signal source. Using a 3.5 MHz crystal, you have a band edge marker. With the transmit crystals on a Twoer or any other transmitter you have instant frequency spotting without modifying the circuit of the transmitter. Of course, the signal source can be used to tune up any receiver, peak tuned circuits, be an rf source for an antenna noise bridge, and so on.

RECEIVER TWEAKER

Malcolm Oakes K6UAW

I've found that the singlemost piece of needed test equipment by the amateur on FM is a receiver alignment generator. Most of us, however, do not have access to a signal generator. (Come on now, you wouldn't really call that *TV thing* a signal generator would you?)

The unit to be described is a very functional device that will allow you to scrape every ounce of sensitivity from your receiver. The generator can be built so small you can carry it around in your shirt pocket. Compactness, combined with its battery-powered portability make it ideal for servicing mobile receivers. Stability? It's crystal controlled and is as good as the rock you plug in (you obtain the rock from your transmitter). Output reactance? Nearly zero degrees, allows proper tuning of rf stage. The attenuator shown does not have a great deal of dynamic range due to distributed capacity of the potentiometer. However, I said before, the unit was "functional" and it is just that. The signal can be attenuated into the noise and brought up to approximately a 30 uv level; overly sufficient for a normal alignment.

Construction

The circuit layout is not particularly critical, and if laid out in a manner similar to the schematic, no problems should be encountered. The attenuator section should be completely shielded away from the oscillator and multiplier stages, so rf leakage will not be a problem. A crystal socket should be provided so the unit is versatile for any frequency. However, if you plan on using it on only one channel and can spare a crystal, build it with the crystal inside. Two glass piston screwdriver adjusted trimmers must be provided (to "rubber the crystal" and tune the output to resonance) as front panel controls.

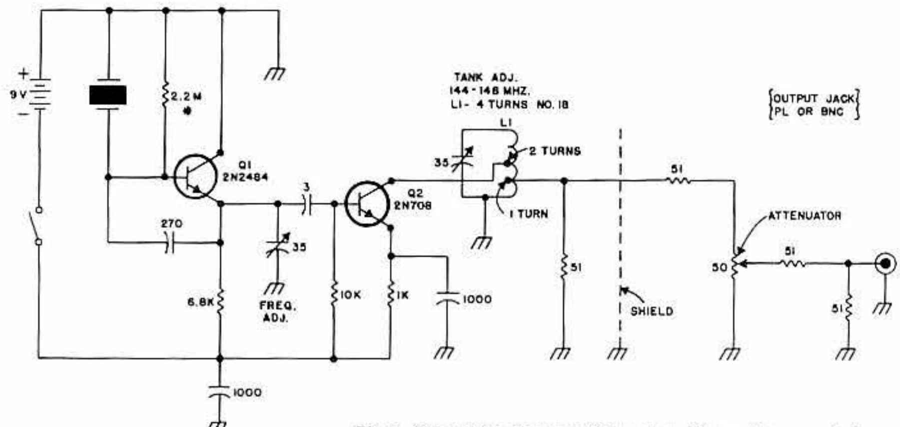


Fig. 1. Schematic diagram of Tweeker. The registor marked * may have to be changed to one of lower value if the recommended transistor is not used.

Circuit

Transistor Q1 in the first stage is a crystal oscillator which is very loosely coupled to Q2 the multiplier. This stage is biased into "class C" so as to multiply the 6 mhz crystal 24 times, up to the two-meter band. (3 mhz crystals will also work at a multiplication of 48.) Another important function of this stage is to attenuate the oscillator output (about 6-7 volts peak-to-peak) to a level usable at the two-meter frequency for alignment – 30 to 40 uv. The potentiometer adjusted attenuator takes the signal down to a level as desired by the operator.

I developed this unit for use on two meters. Several have been built and all work fine. But, for those of you who need a six-meter generator, this same circuit should work fine with the only modification needed being the final tank frequency. (A few more turns on the coil and a slightly larger trimmer capacitor.)

Adjustment and operation

Connect the output of the generator to your rig. Plug in a crystal and tune for zero (with frequency adjustment) on the discriminator (center frequency). Now, looking at the first limiter voltage, peak the final tank. Attenuate the generator as necessary to avoid saturation of the limiter. Repeat as necessary until a definite peak is reached.

If the generator will not go down into the noise with the attenuator control, the final tank may be detuned as necessary to provide the desired range on the attenuator.

CITIZENS BAND ALIGNMENT AID

Edward Lawrence WA5SWD

It is obvious that the front end of a receiver should be tuned to respond equally well across the band, and thus have consistent sensitivity at any frequency in the band, if maximum usefulness is to be obtained. The usual method of insuring reasonable results is to tune at the middle, and check the ends. This is rather spotty, at best, as it would be better to check all channels. This is involved since you must set both frequency and amplitude 23 times in a single pass.

Naturally, a good sweep generator could be used, and the rf-mixer tracking set with it instead, but this was not available to me at the time. The circuit in Fig. 1 was originally a super-regenerative receiver taken from the GE Transistor Manual. These, as is well known, tend to spray a lot of rf back out the antenna. With this in mind, I listened with a communications receiver and noted strong modulation products about 100 kHz above and below the "carrier." Deducing this to be caused by the quench frequency, I brilliantly decided to drop the quench frequency into the audio range, by increasing the capacitance across the base bias resistor. Lo and behold! Suddenly the entire Citizens Band was alive and jumping with a mass of "line noise," which at first appeared to be like

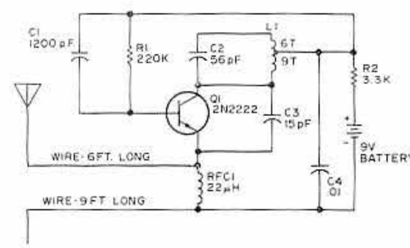


Fig. 1. Schematic of the alignment aid. L1 is 15 turns No. 22 tapped at 9 turns from the collector end. No switch is shown, so remove battery when not in use.

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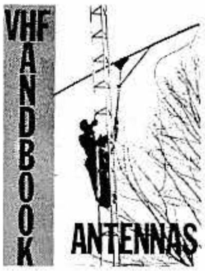

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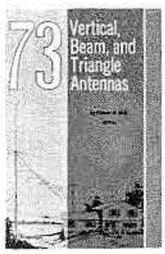

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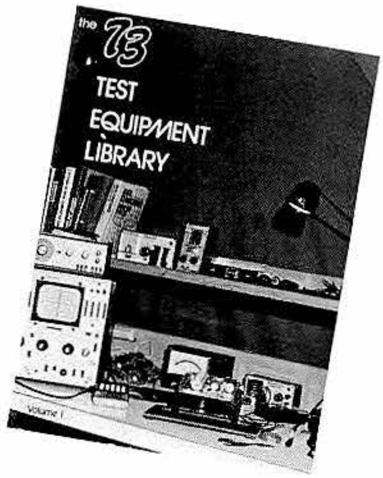

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Fig. 2. Full size PC board layout (foil side).

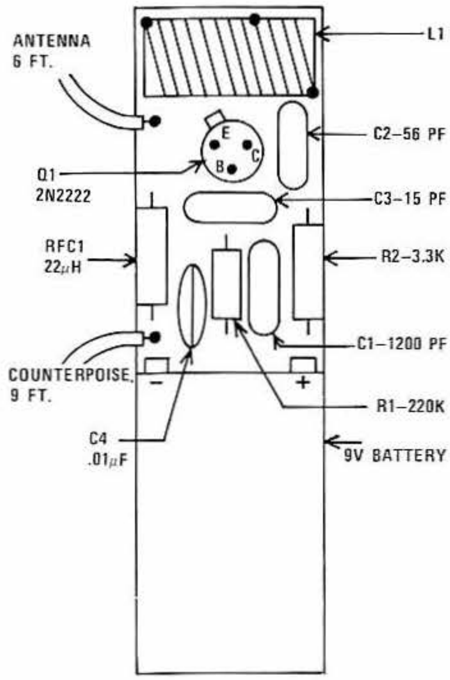


Fig. 3. Component side parts placement.

natural noise. Then I turned on the BFO, which showed it to be many, many, many closely spaced "carriers." I presume the lower quench frequency develops a much larger bias swing on the base of the transistor, FM'ing it across the entire band. This stuff is concentrated in the region of 27 MHz, with very little spill-over into 10 or 15 meters, although the level across the design range is rather constant. The nearly constant rf level is what I needed to simplify tuneup of the front ends of the units I was working on.

Figure 2 is the layout of the P.C. board I made to facilitate reproduction of this useful circuit for a few interested friends and Fig. 3 is the component layout.

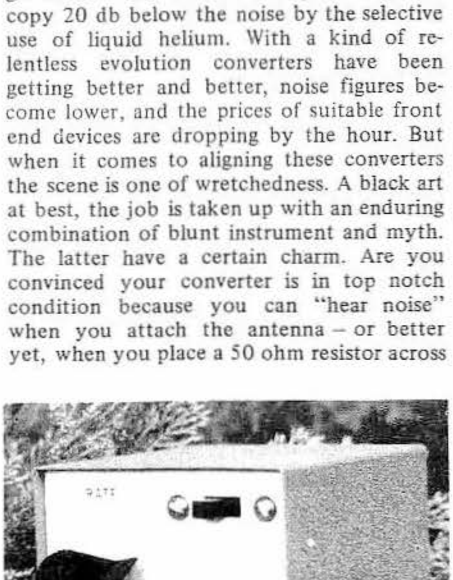
I used 6 ft of wire as an antenna connected to the emitter side of the rfc, with 9 ft of wire on the battery side of the rfc as a counterpoise. Since this made it a bit large, I carefully hung it vertically in a handy tree nearby. Of course, since this put a strong signal on every channel into every CB receiver within 300 yards, I limited the use of this device to avoid unnecessary interference to the deserving users of the band. However, one fellow accidentally launched his into a tree too high to recover with an over-ambitious heave, and it ran for about a month in the dead of winter in a nameless northern city, helping every CBer for miles around align their sets! It only draws about half a milliamp from a 9 volt battery.

Since I am sure many others would like to align their 11 meter receivers for optimum results, I am presenting this circuit as a very low cost and worthwhile aid.

FET CHIRPER

Chuck Hines K6QKL

The Chirper is an automatically keyed, crystal controlled, signal source which may be used to optimize the signal-to-noise ratio of a receiving converter. Homebrew or commercial, converters are a common thing around an amateur station. And, most of the VHF Tribe have read thru a jungle of esoterica dealing with low noise front ends, the velvet beauty of FET's on Two, noise generators and eternal truth, and how to copy 20 db below the noise by the selective use of liquid helium. With a kind of relentless evolution converters have been getting better and better, noise figures become lower, and the prices of suitable front end devices are dropping by the hour. But when it comes to aligning these converters the scene is one of wretchedness. A black art at best, the job is taken up with an enduring combination of blunt instrument and myth. The latter have a certain charm. Are you convinced your converter is in top notch condition because you can "hear noise" when you attach the antenna – or better yet, when you place a 50 ohm resistor across



the input? Try putting a complete short across that same input. Shorts aren't much good as noise sources. You'll find the short gives about the same change in noise level as the 50 ohm termination. What has changed is the impedance the front end "sees". The same is partially true of the noise from the antenna. Neither is indicative of the performance of the converter. Peaking the system up for maximum on either a weak signal or on noise gets you nowhere. The diode noise generator which every VHF book of substance describes is a good and useful tool when used properly. The assumption is that everyone already knows full well how to use it and does so. Few in fact do.

I'm sure you've read of it before in many places, but a little redundancy is in order. The noise with which you are concerned is the noise generated *internally* by the first tube, transistor, or other active device the signal encounters upon its arrival at your converter. By fiddling with the external reactances, adjusting the voltage and current and otherwise manipulating the things soldered to the device, one may minimize the internally generated noise. At the same time the reason the front end exists is to amplify the signal. One usually desires as much amplification possible, short of smoke and oscillation. Minimum noise and maximum amplification is the game. Though the two are not quite mutually exclusive a certain amount of compromise takes place. Thus, the signal to noise ratio. When aligning a converter's first stage every adjustment effects *both* signal and noise. Given a constant signal source coupled into the converter thru an appropriate impedance, the job is finished when the front end has been adjusted for the greatest *difference* between signal and noise of which it is capable.

The Chirper is designed to help you do all this by letting you see what effect each adjustment has on both signal and noise. The TIS34 oscillates at a frequency controlled by the crystal. With the constants shown, that can be anywhere between 8.2 and 36 MHz. The variable capacitor must be adjusted for resonance. It isn't particularily critical but its setting peaks the *rf* output at either the fundamental or some harmonic. For 6 meters an 8.35 MHz crystal is used. A 9.0 MHz rock will pin the meter when the

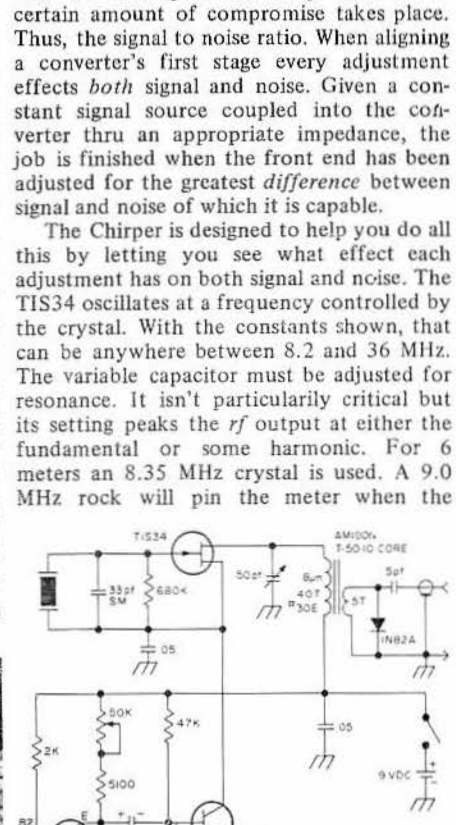


Fig. 1. Schematic of the FET chirper.

Chirper is connected into a 2 meter converter. The Amidon toroid is wound with No. 30 enameled, 40 turns for the primary and 5 turns for the secondary. After it is wound, spread the turns to fill the toroid and paint it with Q dope. The diode and 5 pF coupling capacitor are connected with the shortest possible leads, the diode being grounded at the *rf* connector. The harmonic output is excellent and quite useable at 1200 Mhz.

The oscillator is turned on and off by a multivibrator combination of unijunction and NPN transistor adapted from the *G. E. Transistor Manual.* The rate at which the multivibrator cycles is determined by the large value capacitor, in this case 33 mF. The polarity of the capacitor is critical. Observe it. To increase the cycling rate, decrease the capacitance; and, to decrease the rate, put in a larger value. Mine cycles a little under once per second. A value somewhere between 30 and 40 mF should suit your needs. You are better off scrounging some odd value from a defunct computer board because of the tolerance problem. If it says 33.2 mF, its probably pretty close to that value. Otherwise you're dealing with tolerances of plus 100% and minus 50% or something equally grotesque. The 50K pot determines the portion of the cycle during which the oscillator is On and is mislabeled rate on the Chirper shown. The HEP-310 is generally available and inexpensive. Other unijunctions were not tried. On the other hand almost any NPN of reasonable quality will work in place of the 2N718. A number of 2N388 and 2N3478's were tried and behaved well. It's a good place to use those transistors you've replaced with FET's. Use something with a Beta of 50 or better for best results. The 5100 ohm resistor in series with the pot is for current limiting. It's deletion will increase battery drain with no increase in Chirper performance. Normal current from the 9 volt battery is around 5 mA.

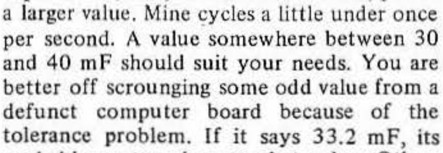
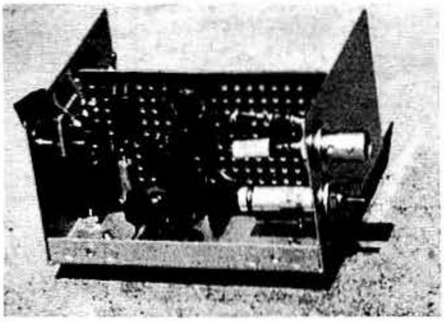


Fig. 2. Test set-up for converter alignment.

Construction is non-critical and pretty much a matter of taste. Mine is built on a piece of vector-board and mounted in a Suzurando box, model M-1N. It measures 3¼ X 2 X 4" and there is still room inside for additions. It sells for 330 yen, about 92c. A slide switch is used to turn the power on and off. Paint one well of the slide switch with red paint – Testor's Pla, a model plastic paint, is good – and the switch will indicate its position. Red for On and black for Off. It saves batteries. Check your work and the polarity of the large capacitor. Re-check the connections to all the semi-conductors. With four different kinds of devices things can become confused. Set the pot to the middle



of its range. Insert a crystal in the socket. Connect the Chirper to your converter, turn the switch on and adjust the variable capacitor for the highest reading on your S-meter. The oscillator will turn on and off. Varying the pot will extend or diminish the amount of time the oscillator is on. Whatever you do, *don't connect the chirper to an external antenna.* The harmonic content is high and even at this power level is sufficient to cause severe interference to television receivers within a two block radius.

For converter alignment, the test set-up is illustrated in Fig. 2. The Chirper is fed to the converter thru an attenuator for two reasons. First, the power output of the Chirper is too high on six and two. You don't want to align with a forty over nine signal. Something around S-5 to S-7 is desired. Second, the attenuator maintains a 50 ohm termination for the converter. A converter cannot be aligned with a floating input impedance. Fixed and variable attenuators of excellent quality are available thru surplus and homebrew data is available. See *73,* January 67, p. 40 for one that will do the job. Turn the receiver avc off. The read-out options are diverse. The best is probably a scope connected to the *if.* A vtvm can be used, connected to the audio output. And, the S-meter can be used with the avc on *fast.* This will vary with the receiver and it's particular time constants. What needs to be avoided is avc pumping that interferes with your readings.

Turn the Chirper on, adjust the attenuator for a convenient signal level. When the oscillator is on, you're reading signal. When the oscillator is off, you're reading noise (on the scope, vtvm, S-meter, etc.). As you make adjustments on your converter, observe the effect on both signal and noise. Adjust for the greatest difference between the two. Turn the Chirper off and re-check the converter neutralization. If necessary, re-neutralize the converter and go thru the whole thing again. Talking about it makes it seem somewhat complex. It really isn't and the whole business won't take long once you've done it. It will become quickly apparent that highest signal level and lowest noise level do not coincide. You can vary the bias, voltage, etc., and observe the effects of each on the signal-to-noise relationship. You can, in short, optimize your converter's performance.

A number of things can be done with the Chirper. There is room in the box to build another oscillator section connected to the transistor collector, operating in parallel and simultaneous with the first oscillator. By appropriate choice of crystal and attenuation, both signals can be introduced into the converter in order to adjust the mixer for minimum cross modulation.

Or, instead of using an oscillator at all, you can use the switching section of the Chirper to key a noise generator on and off. This has a certain attraction where an integrating network is used prior to a vtvm. In this case noise is used as a signal.

In spite of it's name, the Chirper is remarkably stable. Chirp becomes apparent from two meters or so, but is no problem. Build one and take the myths out of your converter.

UHF SIGNAL SOURCE

Bill Hoisington K1CLL

The UHF experimenter learns early that the UHF ham bands don't always furnish a signal when you need them. When I build receivers and converters for 432 and 1296, I find that I need a small signal generator for alignment and band spotting. Not much power is needed for this work, so transistors are the ideal choice for generating the signal. This signal source is in three parts, a 432 source, a tripler to 1296 and a modulator.

The 432 Driver

I started with a low-cost 27 mc crystal that I found in my junk box. (Never mind how it got there!) I used my usual phase-reversing crystal circuit followed by a bunch of doublers. Lower-priced transistors were used in the early stages and the UHF ones saved for later. You really need good ones on 1296! Each doubler is biased from rectification of rf from

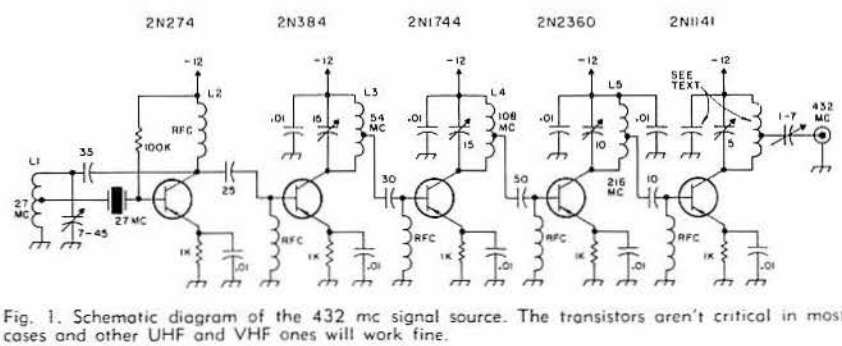


Fig. 1. Schematic diagram of the 432 mc signal source. The transistors aren't critical in most cases and other UHF and VHF ones will work fine.

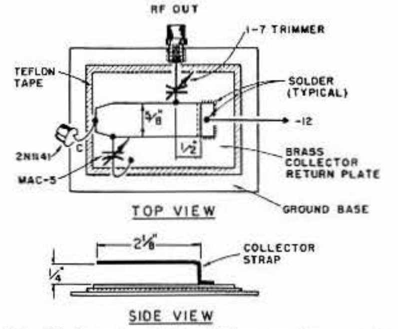


Fig. 2. Details of the 432 mc collector circuit.

the previous stage. If you need more output than this circuit gives you, use less than a 1 k resistor in the emitter, but watch out for high collector current. **Fig. 1** shows the schematic of the 432 mc generator and **Fig. 2** gives details of the 432 mc collector circuit.

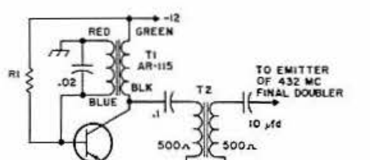


Fig. 3. The tone oscillator for the 432 mc signal source.

The tone modulator

This is a crude modulator (**Fig. 3**), but it works. The modulation transformer is not absolutely necessary, but seems to improve results. You can apply the modulation almost anywhere for this application, but modulating across the 1 k emitter resistor gave the cleanest sound with the doubler used.

Now to 1296

I built this tripler to 1296 just for the fun of it. But it worked quite well. I normally don't hold with triplers at this frequency, but it's an easy way to get 1296 mc energy from the 432 mc driver. The transistor I used was a Motorola 2N1141. It's several years old and there are better ones that are far cheaper now. But it does work on 1296. I couldn't get it to work with grounded emitter, but grounded base is fine. Fig. 4 gives the schematic but Fig. 5 gives the details, which are vital. The

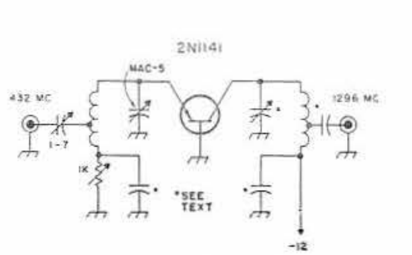


Fig. 4. Schematic of the 1296 mc tripler.

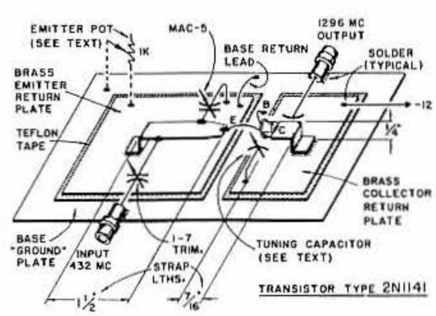


Fig. 5. Pictorial layout of the 1296 mc tripler.

input on 432 tunes very nicely. But I had to reduce the emitter resistor in the doubler to 432 to get enough drive. It ended up at 200 ohms. The collector circuit is short, but tunes smoothly. The 1296 mc output registers 100 a in the 1296 cavity in the May 73.

You might try a small amount of modulation on the 1296 mc tripler. Also a waveguide attenuator. Be seeing you on 23 cm.

CRYSTAL CONTROLLED SIGNAL SOURCE WITH INFINITE ATTENUATOR FOR 144, 432 AND 1296 MHz

Bill Hoisington K1CLL

One of the most useful test-equipment gadgets the homebrewer can build is a signal generator. The one described here is of commercial quality and it can be completely contained inside a waveguide. Positioning, by sliding along the waveguide, provides a variable-strength stable signal of one millivolt, one microvolt, one nanovolt, or less, dropping down gradually to a true zero. It does this in a perfectly smooth fashion without steps or jumps so that every fraction of a decibel in lower noise figure shows immediately on the slide dial. What's more, the slide can be calibrated so that FM'ers can use the device for directly measuring receiver sensitivity in tenths of a microvolt.

In building a 6 meter receiver recently for maximum absolute sensitivity I naturally had to check especially on the first-stage rf transistor and circuit for minimum noise figure. (For this type of work you *must* have a signal generator capable of being attenuated out of sight with any receiver you can buy for any money.) The usual generators on the market under $100 do not do this. And many of the very expensive generators get so leaky that they have to be used 200 ft from the receiver. At any rate, the generator described here can be made up quickly and at low cost, and it *is* stable, reliable, and infinitely variable.

Waveguide

The only possible difficulty might be in obtaining the piece of waveguide needed. The piece I used is 4¼ in. wide by 2 1/8 in. high, and is 24 in. long. If you have a choice, get a piece a little longer. You could make up this item out of brass or copper if you had to, because in this case it is not used to *carry* energy but to *attenuate* it, so the worse you make it the better!

The waveguide *must not* have any holes in it and should be reasonably smooth inside; otherwise your dial would not read smoothly in attenuation. You *could* use copper or aluminum drain pipe, although I have not tried them yet. Working directly on the rf, this attenuator is good for any kind of modulation, including SSB, FM, pulse, or what have you.

Construction

Figure 1 shows the basic idea. When the signal generator plate is close to the

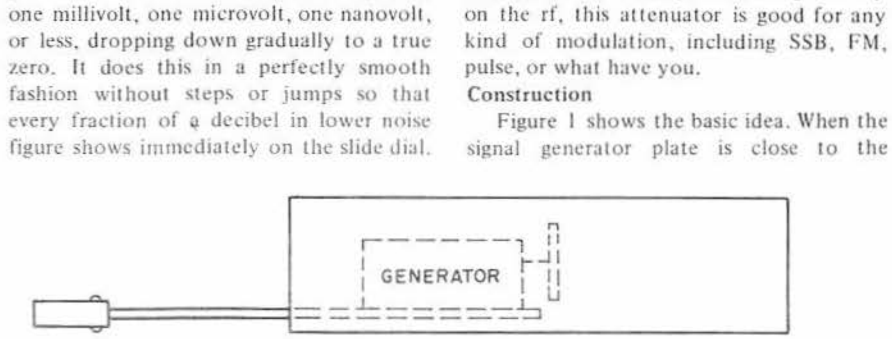


Fig. 1. Sketch shows plan-view layout of unit inside waveguide attenuator. The oscillator unit is mounted on a flat wood or cardboard strip that can be calibrated to give accurate indications of output signal.

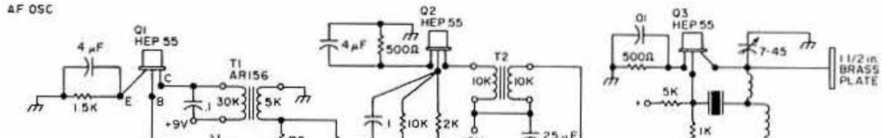


Fig. 2. Schematic of generator. This entire assembly about 3 x 4 in. including small 9V battery and switch must be entirely inside the waveguide. No wire or metal of any kind can be brought outside.

receiver pickup plate, you can get about 100 mV of signal into the receiver, and it is handy for checking diode receivers. When the two plates are about 8 in. apart, the signal is just detectable on a good receiver. Additional spacing between plates amounts to "waveguide beyond cutoff." I do not believe that there is any receiver in the world that can pick up the signal much beyond the 8¾ in. point.

Pretty soon in your receiver "peaking" work you get to that signal that may be but a tenth of a microvolt or so, and you begin dreaming about cryogenic front ends, masers, and such. As mentioned, every fraction of a decibel lower in noise figure, every improvement in sensitivity comes out rigorously and relentlessly on that slide dial. You can easily check which of your low-noise transistors is really low, whether that MOSFET will do a better or worse job for you, and in which circuit.

As you go up in frequency you may have to make smaller and smaller oscillators in order to fit in smaller waveguides to get the cutoff effect. (That will not be a problem if you read 73; the May issue described a "postage-stamp-sized" rf generator that is an ideal candidate for the signal source.)

Circuit

A crystal oscillator, an af oscillator, and a simple class A modulator do an excellent job to start with. Figure 2 shows the present unit as used on 6 meters. It must be stressed again that no wire or other piece of metal may be allowed to reach the outside from this assembly. I'm making up another for 2 meters soon (still my favorite band) and will try one on 450 a little later.

Audio

A controlled-feedback transformer-coupled af oscillator does a good job in furnishing a sine wave. A Motorola HEP55 is used for the oscillator, with feedback to the base from the collector through transformer T1, controlled by resistor R2. Audio output is taken off the 5 kΩ winding of T1, is fed through R4 the modulation control, and then to the base of af modulator Q2. Transistor Q2 is set up for low-power class A operation because not much modulation is needed for the signal generator. Transformer T2 is an old 5W unit from "tube-type portable" days. The secondary of T2 feeds a modulated +9V signal to Q3, the crystal-controlled 50 MHz oscillator.

This rf oscillator is one of my negative-feedback jobs with phase reversal in the crystal. A 1½ in. square plate is tied onto the collector, radiating energy to the receiver pickup plate facing it inside the waveguide. This energy is rapidly attenuated as you move the plates apart, and should be impossible to detect after some 9 or 10 in. of separation.

Once again, do *not* bring any wires or any other metal or conductor out from the oscillator assembly. If you want an outside controlled switch or other control, bring it out as a wooden dowel handle.

That's about it. Tune everything up outside the waveguide on the bench; when you're satisfied, plug your best 6 meter receiver into J1, push the oscillator plank along the waveguide (or rather I should say pull it along) away from J1. You'll get a surprise! Hope this helps you with your low-noise receiver work. It did a lot for me.

LOW COST 220 MHz SIGNAL GENERATOR

Bill Hoisington K1CLL

This article describes the design and construction of an easy to build, inexpensive, crystal controlled signal generator for the 220 MHz band, including a very low cost attenuator that goes from a quarter volt down through 1/20th of a microvolt and on to a real zero (of rf power). It is very useful for receiver front-end tuneup, low noise tests, and as a portable field generator for overall antenna tests through the receiver. For signal identification purposes, af and FM modulation are included.

If you really want to fight for a low-noise front end, this piece of equipment will be of great assistance to you, because the attenuation really is infinite and without any difficult bypassing or shielding.

Design of the attenuator.

Infinite attenuation is achieved here by the use of a 50¢ piece of aluminum tubing, as shown in Fig. 1. You cannot drive 220 MHz signals more than a few inches down inside of a piece of aluminum tubing. By putting *everything* – battery, on-off switch, circuit and all – on the movable generator strip and sliding it in and out of the tubing, you avoid all touchy, difficult and expensive bypassing, costly attentuator pots, shielding, etc., and provide a simplified means of varying the attenuation with stable, smooth, easy repeatability. Calibration is of the slide rule variety and also simple as far as writing down the microvolts on the scale is concerned.

This principle is older than radio tubes; in fact Sir Oliver Lodge used it in his 1890 microwave work.

Attenuator Construction Details

Figure 1 tells most of the story, with details in Figs. 2 through 9. An adequate rf seal can be made at the pickup end of the aluminum tubing, standard TV masting, 1¼ O.D., by 2 or 4 tabs in one end as in Fig. 3 and bending them back as shown, then cutting off the excess tubing. Install the pickup, plate, output jack, and end plate as shown in Fig. 1. I used time-saving external mounts for fastening it down to the wood baseboard as shown in Figs. 2 through 5. Drill a ¼ in. hole for a screwdriver as in Fig. 2, and use angles for the pickup end. Figure 2 also shows the scale in use for attenuation settings, and Fig. 3 shows pointer details.

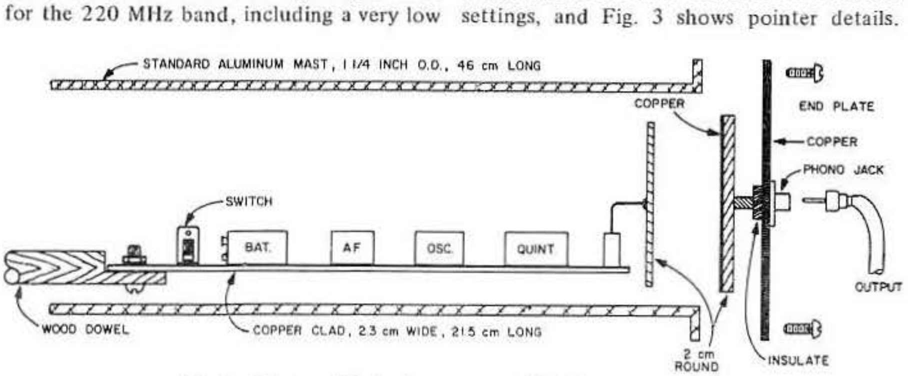


Fig. 1. Sideview, 220 signal generator and infinite attentuator.

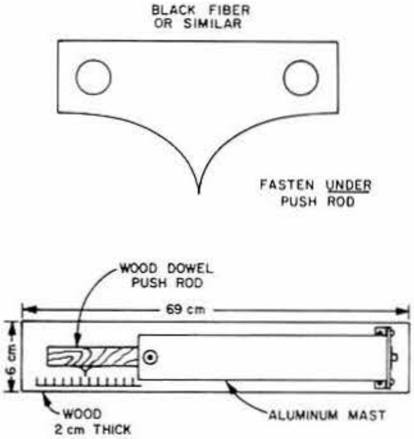


Fig. 2. Top view of the 220 signal generator and details of the calibration pointer.

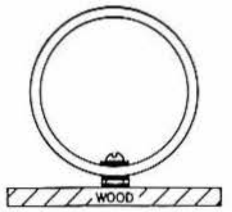


Fig. 4. Open end view.

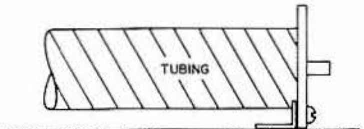


Fig. 5. Side view.

The output goes to the antenna plate on the forward end of the baseboard plank. When this plate is moved all the way in so that it is only ¼ in. from the cable pickup plate in the end of the aluminum tube, a full scale reading may be obtained on a 50 microamp meter on the output of a tuned diode detector (see Fig. 9). My first model here has marks on the scale (see Fig. 2) for 1 rf stage; 2 rf stages; mixer (feeding into a good i-f strip); mixer plus 1 rf, etc. At the 1 rf plus mixer, you begin to hear all the repeaters within 100 miles or so. With 2 rf plus mixer (followed by a sensitive i-f of course) you are really getting sensitivity. This is where you put a scope in line in order to have an electronic comparison point for signal coming out of the noise purposes, and then can really get into the low-noise bit, if you have a hermit location. Just happens I have one here. When I hear the noise of a car, it's a visitor!

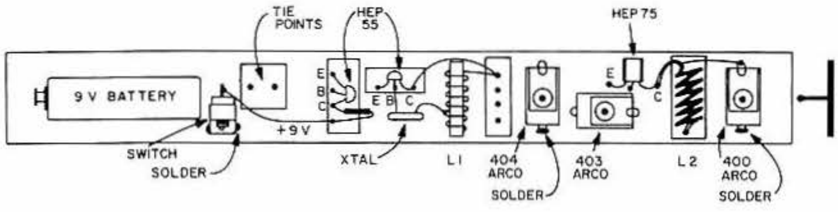


Fig. 6A. Layout, top view.

Figures 6 and 7 show pictorials of the layout, top view and side view.

The Generator

Nothing too fussy here, but attention to details will assure reliable af and rf oscillation at low power and low battery drain and good frequency multiplication. Figure 8 shows the schematic with the details of the two oscillators, the crystal in the 44 MHz range, and the quintupler. The af uses a standard circuit which, however, has one item to watch. Contrary to a transformer coupled circuit, which is seldom mentioned, this twin-T job has a nasty trick of not starting every time. However a small cap from collector to ground cures this and makes it 100% reliable in that respect. The emitter being grounded, I suppose this establishes the correct in-phase relation with the collector, in which both of these elements should be in phase. You can put a small trim pot af gain control between the modulator and the oscillator if you wish, watching out for dc voltages of course. As shown here, there is plenty of modulation for signal identification, both AM and FM.

Referring to Fig. 8, at the left is the af oscillator. It is not down symmetrically, but you can note the two 22K resistors and the two .02 frequency settling caps, along with the .05 and the 2.2K terminating the lines. All of these set the frequency, and to change the frequency you should vary all of them in at least their approximate present ratios. It is around 500 cycles as shown. Do not forget the "starting cap" from collector to ground.

This audio is fed to the base of the multiplier where it provides some AM and some FM modulation for signal identification purposes. When working with receiver oscillators, and in particular with high-ratio multipliers, this is very important. It may also be locked into any old scope sync for noise figure and sensitivity comparisons. The scope sync gives a reference point where the signal to noise ratio will always be the same, without resorting to guess work. The crystal oscillator is my old tried and true crystal phase-reversing job, which uses negative feedback from the collector coil, which, after going through the crystal, reverses phase and becomes positive, thus assuring oscillation but *only* on the crystal frequency. A HEP 75 (similar to the famous 3866) is used for the quintupler. A lot more output is noted with this powerful but smooth operating old faithful, still good to 450 MHz.

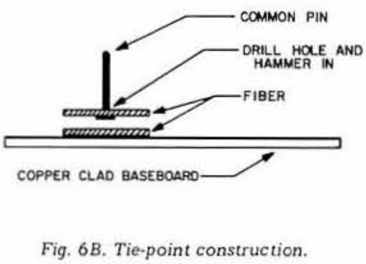


Fig. 6B. Tie-point construction.

Output

You will see for yourself as soon as you start testing that the attenuator is smooth-working and stepless, and that true infinite attenuation is at hand. An rf input state (pre-amp) with a noise figure a fraction better than another shows right away on the scale. For example, adjustment of the fixed bias voltages on the two gates of a 3N200 or 3N201 shows right away on the scale as the

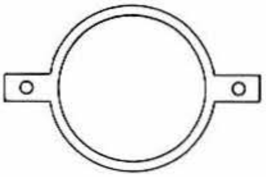


Fig. 3. Cable end view tubing.

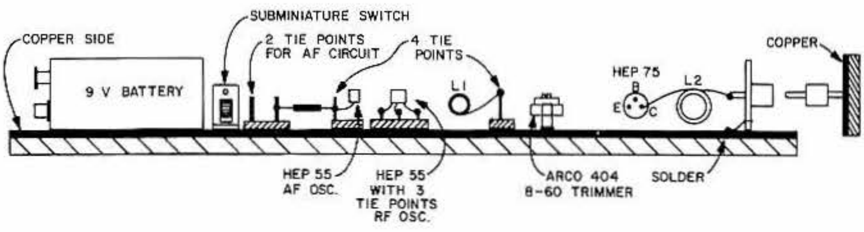


Fig. 7. Side view of the signal generator, 220 MHz.

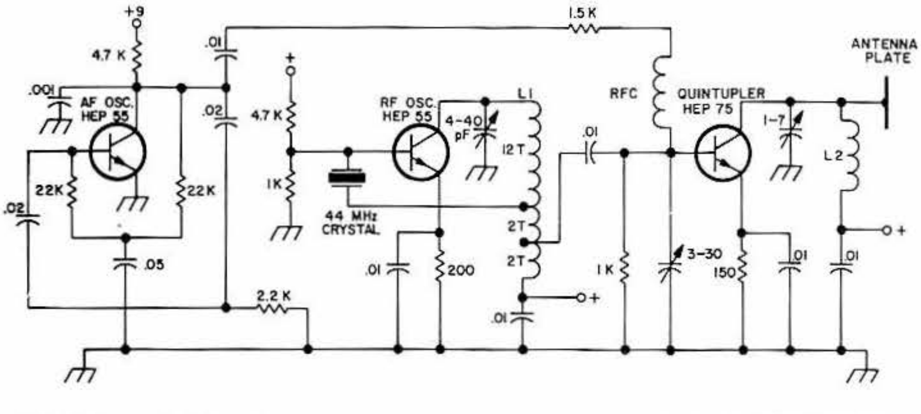


Fig. 8. Schematic. L1 = 16 turns No. 26 output tap at 2 turns, crystal feedback tap at 4 turns, from cold end. Wound on phenloic form .6 cm O.D. L2 = 6 turns No. 18 bare, air wound, .6 cm O.D., 2.5 cm long between tie points. RFC = about 40 turns No. 40, on phenolic form .3 cm O.D., 1 cm long (not critical).

push-rod is moved in and out and the signal is locked onto the scope. This work you can do right on the bench and at low cost.

There is quite a bit of mechanical work in the unit, depending on just how much "finish" you want it to have. You can also bring a dowel rod for "on and off" use. Do not, under any circumstances, bring out a *conductor*. You *can* do this, but only with an extreme amount of filtering, which is not part of this article. Be sure to set up the baseboard, antenna plate and battery first, and get them working mechanically. With a drawn-out shape like this I generally start with a longer piece of copper-clad than needed, build from one end, and then cut off what is left over. Understandably, once you have made the first one you can always see, after it is done, many ways of improving it. However, someone has to make the first one, and that's generally my job.

Antenna and Field Tests

Out of the tubing, and with a small antenna connected via a one turn link around the quadrupler coil and then to ground, returning L2 for maximum output, this little rig puts out a lot of signal on 220. Especially if you reduce the oscillator emitter resistor! Up to several volts of rf can be obtained in a tuned diode receiver if you push things along, which is around 5 to 10 mW. If you place this generator out in a field several hundred yards or more away, you can then line up your antenna on the car or house, check antenna cables, antenna input alignment, and match or mismatch for lowest noise figure, etc.

Front end alignment should first be done with a relatively broadband i-f strip on 10.7 MHz. Be sure nothing metallic on the generator strip protrudes enough to touch the inner wall of the tubing, or "scratch" will occur in the high gain receiver. A piece of thin fiberglass or other insulating sheet wrapped around the whole generator movable plank is a good precaution.

Once again I include a 220 MHz tuned diode detector, which is an absolute must for frequency multiplication, especially quintupling and such, where the other unwanted harmonics are as little as 20% away from the desired frequency. Figure 9 shows this piece of test equipment in pictorial schematic form. Remember, shape is of considerable importance as you go from VHF into UHF. It is quite easy to make the square trough line out of an old piece of copper clad. Or even a new piece! And this particular one described and shown in Fig. 9 goes very well to over 450 MHz and thus is very nice for the next band also. If you make it just as I've shown it, it will do a good job for you.

Calibration will present some difficulties, so line up some other lads around who are already on these bands and get your calibration that way.

So good luck, friends, more coming – lot's more! Keep reading.

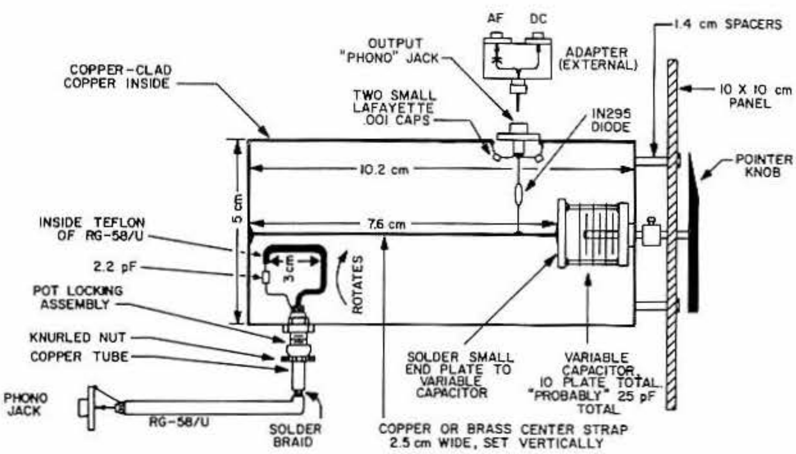


Fig. 9. Tuned diode detector, 160–460 MHz.

UHF SIGNAL GENERATOR

Jim Kennedy K6MIO

Several requirements were the basis for the design of this signal generator: operation on both 432 mc and 1296 mc, high stability e.g., crystal control, variable rf amplitude, provision for insertion of various types of modulation, and lowest possible cost consistent with satisfactory operation.

I had a 27.005 mc overtone crystal left over from a brief period of disillusionment about CB and, since 27 times 6 is 432 which times 3 is 1296, this seemed a likely place to start.

Fig. 1 shows the final result. The overtone oscillator is voltage regulated and is left operating at all times when the generator is on. The crystal is mounted underneath the chassis to protect it from rapid temperature changes from drafts, etc., further enhancing the stability.

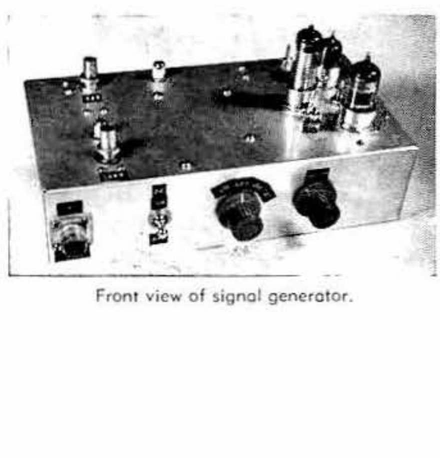
The use of diode multipliers at 432 mc and 1296 mc greatly simplifies developing UHF rf.

Direct coupling the modulation into the cathode of the last vacuum tube multiplier provides a modulation input that will accomodate almost any signal from audio to video, or even pulse.

A four position mode switch on the front panel allows the choice of carrier, no carrier, carrier with 60 cycle modulation and finally carrier with external modulation.

Construction

Building the unit presents no special problems except getting it all under the chassis. The 5 x 9½ x 2½ chassis doesn't leave much useful



Front view of signal generator.

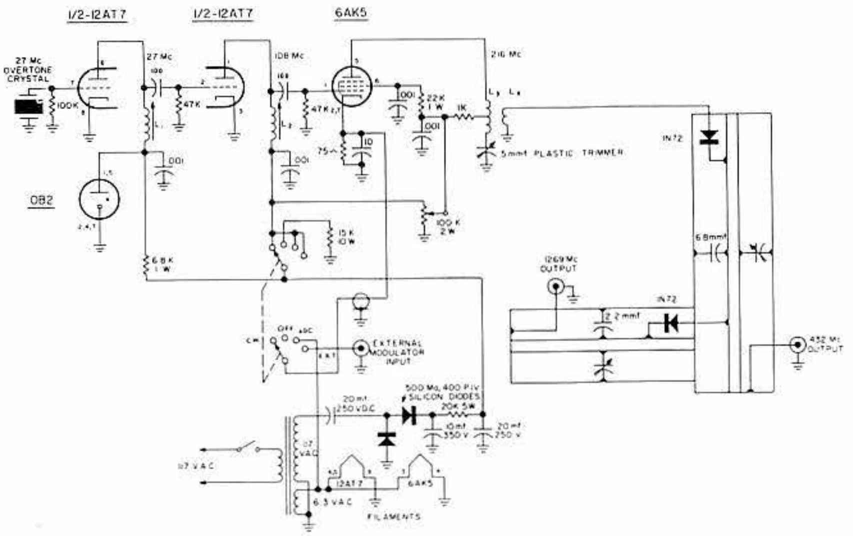
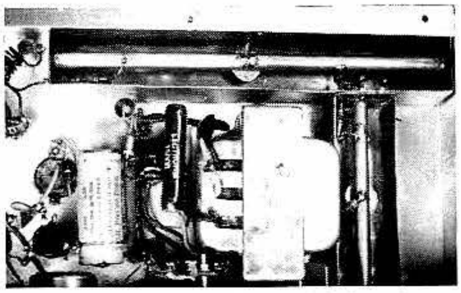


FIGURE 1

L1—10 turns # 28, 3/8" slug form.
L2—3 turns #28, 3/8" slug form.
L3—10 turns #18, 1/2" dia.
L4—3 turns #18, 1/4" dia.



Closeup view showing details of diode multipliers lines.

room to spare, but it does make for a very compact device.

The lengths of the diode multiplier tuned lines were determined primarily by the space available and bear only the slightest relation to the wave lengths involved; hence, it was necessary to pad both lines with additional capacitances in order to resonate them properly.

Both lines were folded from 1/32 inch brass sheet stock. The inner conductors are made from 1/4 inch brass tubing. The 432 line is 1" x 1" x 7". The input diode is tapped onto the inner conductor 1¼ inches from the other end. The signal output loop is about 1¼ inches long. The output diode is tapped 2 inches from the loop end of the line.

The tuning capacitor is made by soldering a 10-32 nut over a hole in the middle of the line shell. This provides the threads for the 10-32 screw which actually serves as the capacitor.

Round ½ inch disks are soldered to the bottom of the center of the inner conductor and to the end of the turning screw to provide additional range.

The 1296 line is similar except it is only 3⅜ inches long. The multiplier diode is tapped on the inner conductor ⅝ inches from one end. The signal output loop is about ¾ inches long and is located at the other end of the line. The tuning capacitor is identical to the one used in the 432 line.

The 15K 10 watt resistor in the carrier OFF position limits the no load voltage from exceeding the ratings on the filter capacitors.

Operation

The tune up of the tube stages can be easily accomplished with a grid dipper. The UHF stages should only need to be peaked with a converter and receiver.

Shields on all tubes and a bottom cover on the chassis are important requirements if stray leakage at the signal frequency or lower harmonics is to be eliminated as a possible source of measurement error. These were removed for the photographs but are always used in practice.

For best results it is a good idea to employ a 50 ohm (or 75 ohm as the case may be) pad between the signal generator and the equipment under test. This will insure that the generator will appear as a resistive load as much as possible. This is necessary if the generator is to duplicate the conditions presented to the receiver by a good antenna.

This pad can take many forms. The two easiest ways to make one would be to use sufficient lengths of some lossy coax. At 432 mc higher, 20 or 30 feet of RG-58 (or RG-59) seems to be quite adequate for most applications. The other approach would involve building a conventional resistor pad into a male and female BNC connector soldered back to back. Fig. 2 shows such a pad.

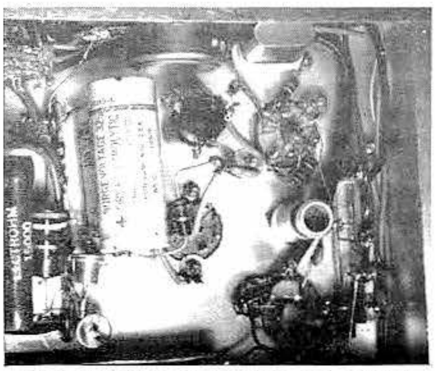
Aside from receiver testing, this device has several other uses to which it can be put. It is also useful as a signal source for antenna tests and it may be used as frequency standard.

This last use can be of great value at UHF because of the persistent problem of crystal tolerance versus frequency multiplication. A converter can easily be 40 or 50 kc or more off of the indicated frequency at 1296 mc. This can be quite a problem if you are hunting for a moonbounce signal through a 5 cps filter.

Though not shown on the diagram or in the pictures, it was found that a 50 mmfd variable capacitor connected across the crystal was sufficient to reduce 27.005 mc to the 27.000 . . . mc required to put the generator on 432.00 . . . and 1296.00 . . . mc. It will probably be necessary to retune the oscillator plate circuit for best operation; some loss in output will be encountered but this should not be a serious problem. However, if such operation is contemplated, it might be of some advantage to obtain a 27.002 mc crystal and employ a smaller variable capacitor.

In order to make the frequency standard really something of a standard, a 1 mc calibration oscillator should be employed. Some harmonic of the oscillator (5 mc, 10 mc, etc.) should be zero beated against WWV. The signal generator should then be zero beated against the 27 mc harmonic of the 1 mc calibrator—presto!—a 432-1296 mc frequency standard.

Though there are many refinements which can be made, the unit described has done a yeoman service in all the varied tasks asked of it.



Closeup showing the oscillator and vacuum tube multipliers.

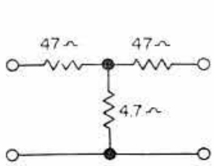


FIGURE 2

Fig. 2. 20 db 52 ohm pad. Resistors mounted in BNC connector.

LAB TYPE IF/RF SWEEP GENERATOR USING ICS

Ray Megirian K4DHC

Just about every kit-type sweep generator on the market starts life out at around 3 or 4 MHz and ends up at 200 MHz or so. This always made analysis or display of 456 kHz i-f amplifier response characteristics a tedious step-by-step plotting procedure or required time out to rig up a temporary gimmick to do the job. No more. The sweep generator to be described here will do the job with ease and precision. Even if you do not intend to duplicate the instrument, you may find parts of it useful for other applications.

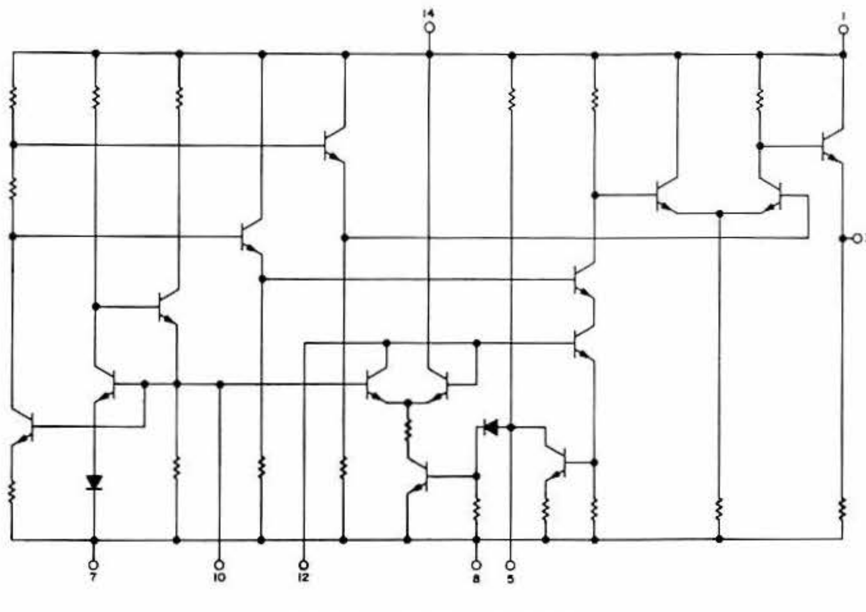


Fig. 1. Schematic of the MC1648 IC.

The generator covers a frequency range of from 400 kHz to 30 MHz in five bands. It can be operated in the CW mode as well as swept, thus allowing it to be used as an ordinary signal generator. Maximum output is 350 mV p-p across 50Ω. When sweeping, the return trace may be blanked or not, as desired. Two calibrated dials are provided for setting the start and stop frequencies and the maximum sweep width would be the entire band in use. The frequencies covered by the five bands are: 400 to 900 kHz, 850 kHz to 2.3 MHz, 2 to 6 MHz, 5 to 15 MHz and 10 to 30 MHz. Sweep time is variable between 20 ms and 6 seconds per sweep. A step attenuator in conjection with a vernier control provide a maximum attenuation of the output of 120 dB. An input is provided for a post-injection marker system built into the unit. A synchronous ramp with gain control is provided for driving the oscilloscope horizontal sweep. Blanking pulses are also brought out to a connector in case they are needed for synchronizing external equipment.

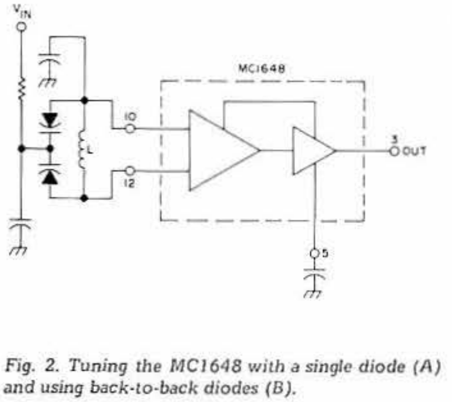


Fig. 2. Tuning the MC1648 with a single diode (A) and using back-to-back diodes (B).

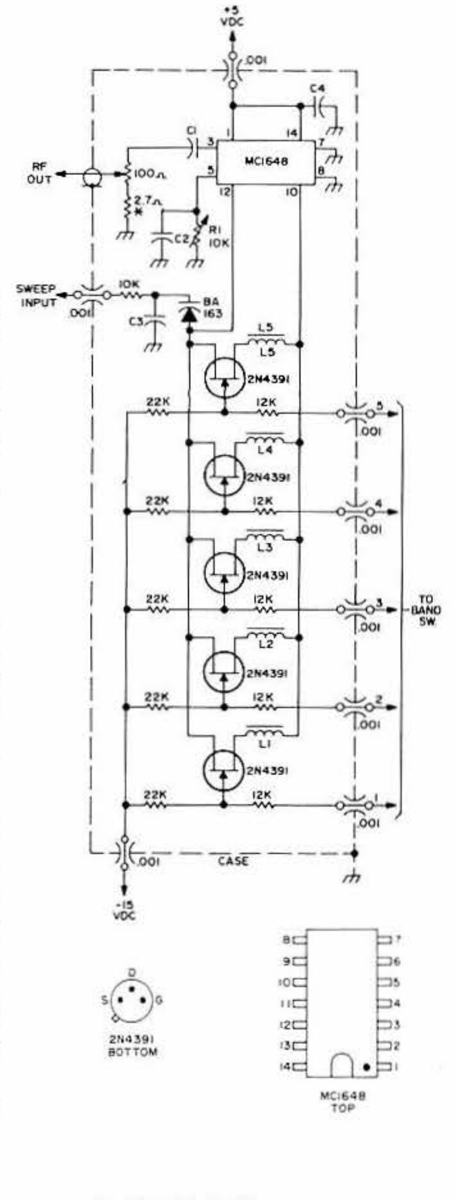
A New IC

The heart of the generator is a new Motorola IC, the MC1648 emitter-coupled oscillator. It was intended for use in phase-locked loop systems operating in excess of 150 MHz, but may be used in many other applications such as this one. The device provides output of high spectral purity and incorporates an internal agc system which simplifies design of the sweep generator by eliminating the need for external leveling. A buffer amplifier and emitter-follower output are also incorporated on the chip, eliminating the need for external amplifiers. Figure 1 is a schematic of the MC1648 IC. Figure 2 illustrates two methods for tuning the oscillator. The device is packaged in a 14-pin DIP and requires a 5V dc supply. Since it was intended to be used with Motorola MECL III logic, either polarity is permissible. A positive supply is used here, connected to pins 1 and 14 with 7 and 8 grounded.

All the information covered by the data sheet for the MC1648 dealt with operation from 10 MHz up to about 180 MHz. Since I was interested in going as low as 400 kHz, I had to do some experimenting with tank circuits. My best results were obtained with the use of cup cores for the two lowest bands. I also found that ordinary molded iron core rf chokes of the miniature variety did an excellent job the rest of the way. Use of these tiny components made possible a very compact 5-band assembly.

The VCO

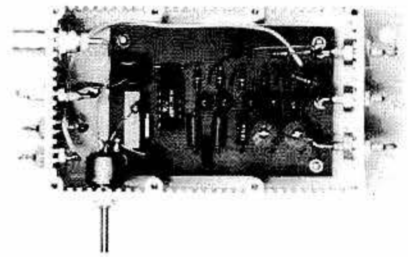
In order to facilitate shielding and simplify construction, electronic band switching is employed. Figure 3 is the schematic for the rf portion of the generator. The 2N4391 J-FET has a low 'on' resistance and works very well as a switch. One of these transistors is placed in series with each tank circuit



ALL RESISTORS-1/4W, 5%
L1-28 TURNS NO. 30 AWG ENAMEL.
L2-12 TURNS NO. 28 AWG ENAMEL
(L1 & L2 MOUNTED IN CUP CORE-See Text)
L3-18 μH MINIATURE MOLDED RFC.
L4-4.7 μH MINIATURE MOLDED RFC.
L5-1.1 μH MINIATURE MOLDED RFC
C1, C2-TYPE 150D TANTALUM-2.2 μF/20V.
R1-BECKMAN 89PR10K 15-T TRIMMER.

*-SELECTED PART-See Text.

Fig. 3. Schematic of the rf assembly using dc band switching.



Completed rf assembly ready for mounting in the cabinet. A plastic version of the 2N4391 was used with a considerable savings in parts cost.

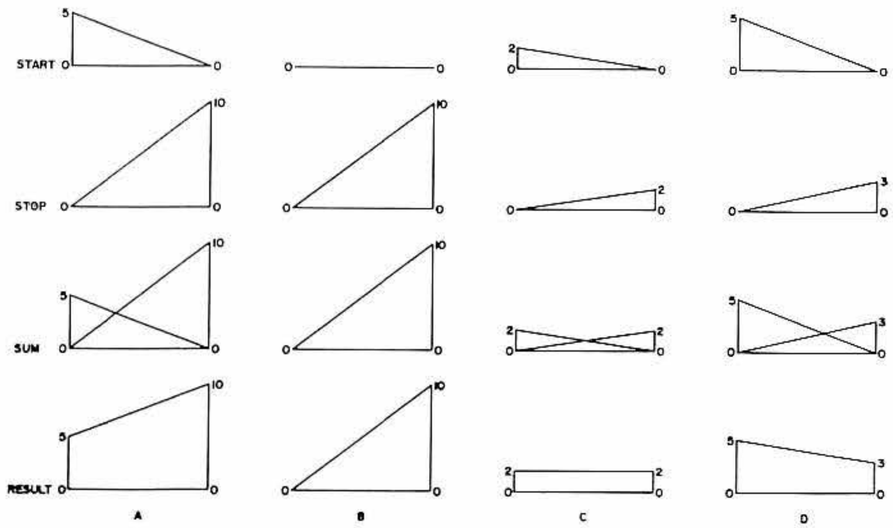


Fig. 5. Pictorial demonstration of ramp generation.

and can be turned on by application of a positive voltage at the gate. This allows the use of a strictly dc-operated remote switching arrangement. The entire assembly is built on a 2 x 3 in. pc board and mounted in a Pomona Model 3306 enclosure with a Model 3328 bottom mounting plate.

A BA163 tuning diode by ITT is used to sweep the oscillator. Although it is intended for bc band use, it performs admirably at these higher frequencies and its high capacitance ratio allows wide sweep excursions. If you are planning to use this oscillator for VHF applications, a more suitable diode would be in order. According to the data sheet on the MC1648, typical maximum output frequency is 225 MHz.

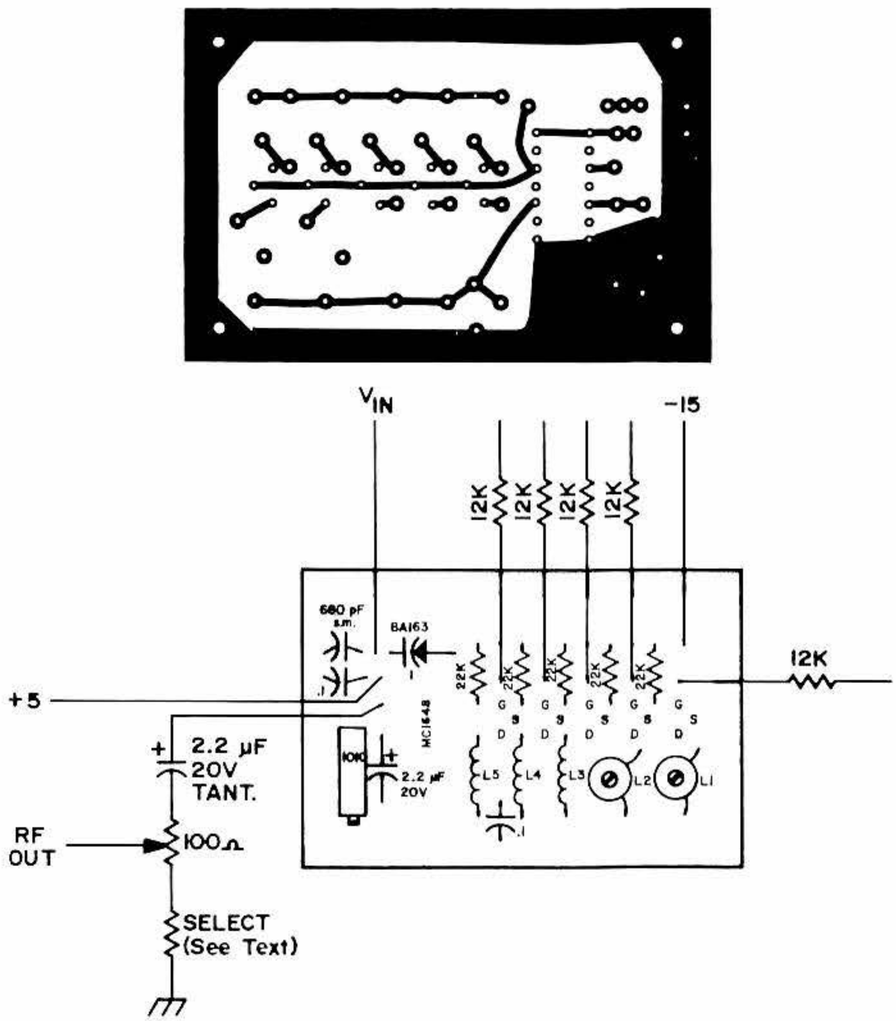


Fig. 4. (A) Foil side of rf pc board. (B) Location of parts on component side.

The vernier attenautor is a 100Ω RV6 style potentiometer mounted inside the enclosure. A coupling and extension shaft are used to bring the control out to the front panel. The value of the resistor at the bottom end of the pot will have to be selected so that a range of 20 dB is provided with full swing of the control. Since end resistance varies from one control to another, an exact value will have to be arrived at experimentally.

The output from the VCO is a square wave. If sine wave output is desired, the agc characteristic may be modified by introducing resistance between pin 5 and ground. The small trimmer incorporated on the board is used for this purpose. It was my experience, however, that this may introduce instability with some MC1648s. Although the trimmer was left in, the one in my unit is turned to maximum resistance where it has no effect and left there. It would do no harm to leave it out altogether since no other changes would be needed.

If any readers are contemplating exact duplication of this generator, you will find the cup cores I used are no longer available. These were Ferrox-cube part number 332P133B4-3C and are obsolete. I had a large number of these on hand left over from another project and saw no sense in buying more. I am sure some of the presently available cup cores will make excellent substitutes. Those used here are about 3/8 in. in diameter and are ungapped. You may have to experiment with the number of turns in the coil to obtain the coverage you require. One handy trick you can pull with a cup core is to rotate the slots in each half so that fractional turns are produced when the coil wires are brought out separately through the

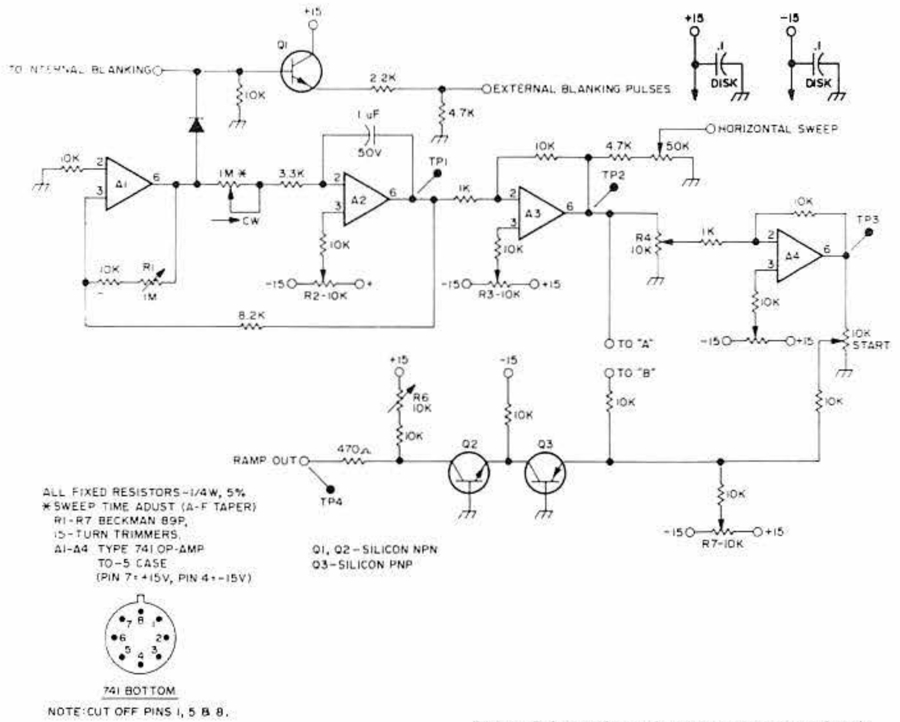


Fig. 6. Schematic of the ramp generator circuit.

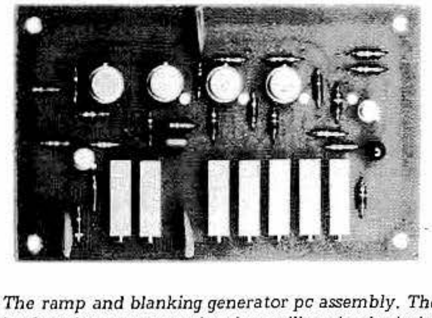
two spaced holes. Exerting pressure on the core by means of the mounting screw will also shift the frequency and is almost like having a slug to tune. Increasing pressure seems to raise the frequency. The rf chokes used for the higher bands may also vary slightly from piece to piece and several may have to be tried to get the desired coverage. There isn't much we can do to alter the frequency where the chokes are used. Of course, slug-tuned coils may be used if the pc layout is modified. I do not recommend their use on the two lowest bands, however, since my results were rather unsatisfactory with this sort of tank circuit.

One final point would be in order before leaving the VCO. Note that the 10 KΩ resistor going to the tuning diode, the 2.2 μF rf output capacitor and each of the 12 KΩ resistors going to the transistor gates are not mounted on the board. One end of each has a hole provided on the board and then the component itself is used to make the connection to its final destination. This saves board space and eliminates separate wires. The small resistor at the bottom of the vernier attenuator is similarly mounted between the board and the bottom lug on the control. These points are more clearly seen in the photo. Also note that the cup cores are fastened directly to the board by means of 1-72 screws into threaded holes.

The Ramp Generator

In contrast with kit-type sweep generators that use the 60 Hz line for sweeping the oscillator, laboratory instruments have internal circuitry designed for this purpose. In our case, as with most sweep generators, a voltage ramp is used to control the oscillator during the sweep period. The circuitry has been arranged so that we can adjust the starting point (dc level) of the ramp independently of the stopping point. This simply means that we can set the frequency at which the sweep starts as well as the frequency at which it stops. We can also control, over a fairly wide range, the time it takes for a complete sweep. In this case, the sweep time is continuously adjustable between 20 ms and 6 seconds per sweep.

To get a better idea of how the ramp generator produces the results we've described above, let's look at Fig. 4. Note that a negative-going linear ramp (start) is combined with a positive-going linear ramp (stop) to produce the resultant ramp being applied to the varactor diode. If either input ramp is zero, the resultant will be the same as the single ramp since adding zero to anything will not change its value. Naturally, if both are zero, the output will be zero and the oscillator output frequency will be constant during the sweep period. The same is true whenever both ramps are of equal amplitude, except that the output will be a steady voltage other than zero. Also note that the resultant ramp could have a negative slope if the 'stop' input is lower than the 'start' input, and the oscillator would obviously sweep down in frequency rather than up.



The ramp and blanking generator pc assembly. The leads going to external points will go in the holes visible on the board.

The schematic for the ramp generator is shown in Fig. 6. Operational amplifiers A1 and A2 form a triangle wave generator with A1 acting as a threshold detector and A2 as an integrator. One half of the triangle (negative-going) represents the sweep period while the other half represents the retrace time. Since a square wave is generated at the output of A1, we have a convenient source of blanking voltage built right in. This signal is positive during the sweep period and is connected to the band switch when Swept 1 (blanked retrace) operation is selected. During retrace the square wave drops to zero and actually disconnects the tank circuit until the next sweep starts. An emitter-follower, Q3, buffers the square wave output for external use.

The output of inverting amplifier A3 is a positive-going ramp during the sweep period and is used for both the 'stop' signal and horizontal sweep for the oscilloscope. Since an additional inversion takes place in the output of A4, the negative-going ramp at this point is used as the 'start' signal. These two ramps are applied across front panel controls which have 6:1 reduction drives and are fitted with dials calibrated in frequency for the five operating bands. The outputs from these two pots are fed to summing amplifier Q1, where the output will be the resultant ramp we discussed above. Because the output Q1 is in the negative region (PNP transistor), a second common-base (NPN) amplifier is used to shift the output back to where it will always be positive.

The ramp and blanking generator is constructed on a pc board 2.6 x 4.1 in. in size. For convenience, all the trimmer resistors were mounted along one edge. As seen in the photo, this board was mounted by means of two small brackets in a vertical position with the trimmers facing up. To simplify pattern layout, unused pins 1, 5 and 8 on each of the four 741 opamps were clipped off right at the case. Color-coded wires were connected to all necessary points on the board before it was mounted, with the leads made long enough to reach their destinations. For those interested in building this unit, a detailed procedure for setting up the ramp generator will be given later.

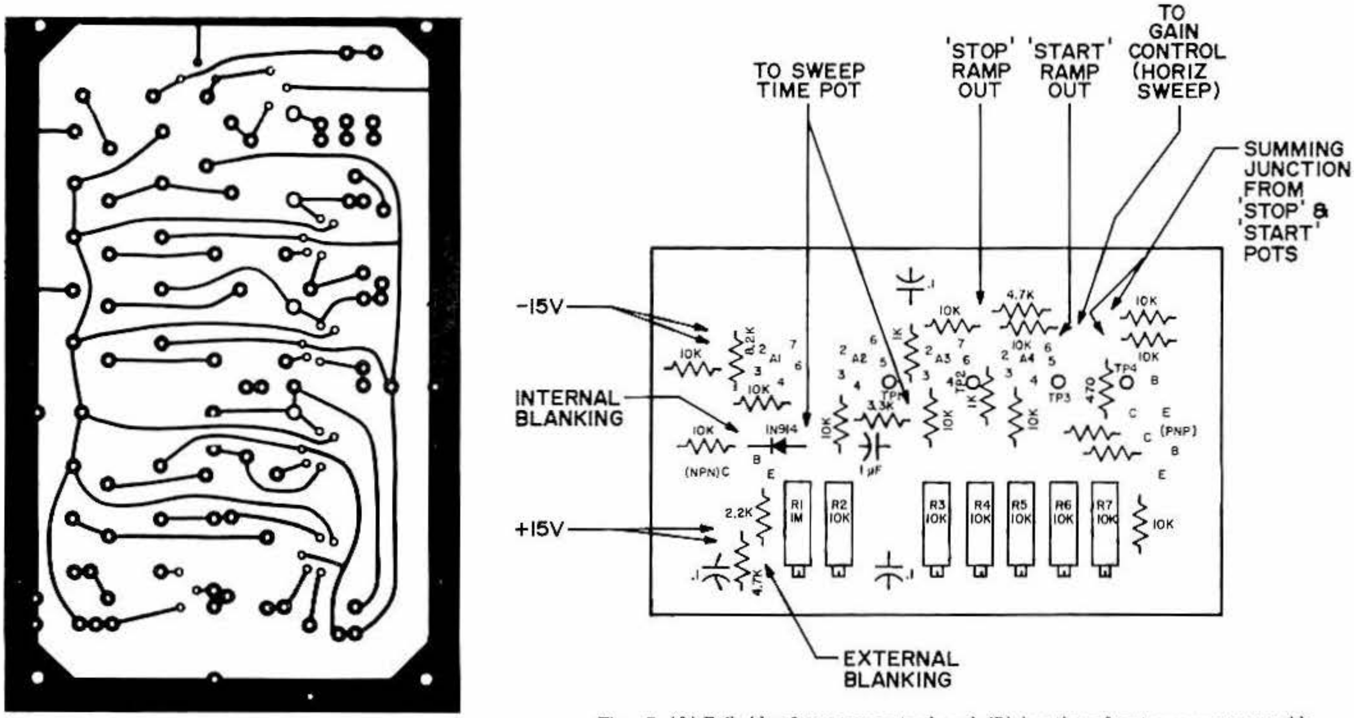


Fig. 7 (A) Foil side of ramp generator board. (B) location of parts on component side.

The Mixer/Amplifier

In order to provide a means for displaying frequency markers, a mixer and amplifier circuit was built into the sweep generator. The schematic for this circuit is shown in Fig. 6. A marker generator was not included inside the sweeper because other rf generators were available for use as markers and the added expense seemed unnecessary. Because the mixer board was to be installed inside a shielded box, dc gain control was resorted to as with the band switching discussed earlier. A 2N4391 is used as a variable resistor to control the signal input to the amplifier stage. This in turn controls the size of the marker being displayed on the curve. A 2N3819 FET is used in a simple mixer circuit which worked the best of several tried. Incidentally, the PNP and NPN transistors used here and on the ramp generator board are unknown surplus silicon units.

The pc board for the mixer is 1.5 x 2.9 in. and is mounted in a Bud CU-124 die-cast aluminum box. Note that here again some of the components are mounted between the board and their external connectors. These include both the 10 pF and 100 pF input capacitors to the 2N3819 and the 10 KΩ resistor going to the gate of the 2N4391.

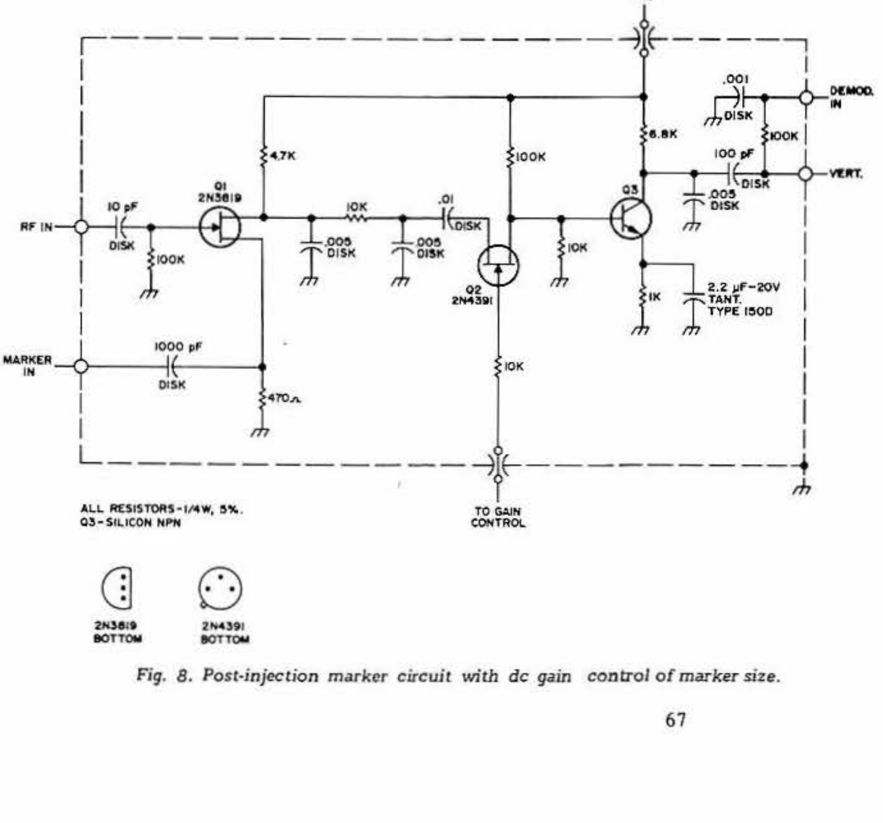
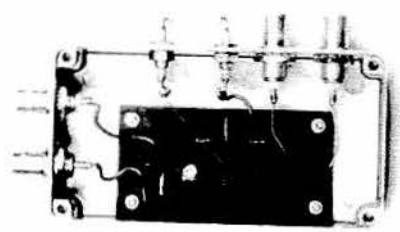


Fig. 8. Post-injection marker circuit with dc gain control of marker size.

The Power Supply

Figure 7 is a schematic for the power supply. Voltage requirements for the sweep generator are +15V, −15V and +5V dc. The current drawn by any of the above circuits runs no more than 30 or 40 mA maximum,



Completed mixer/amplifier board mounted in the die-cast housing.

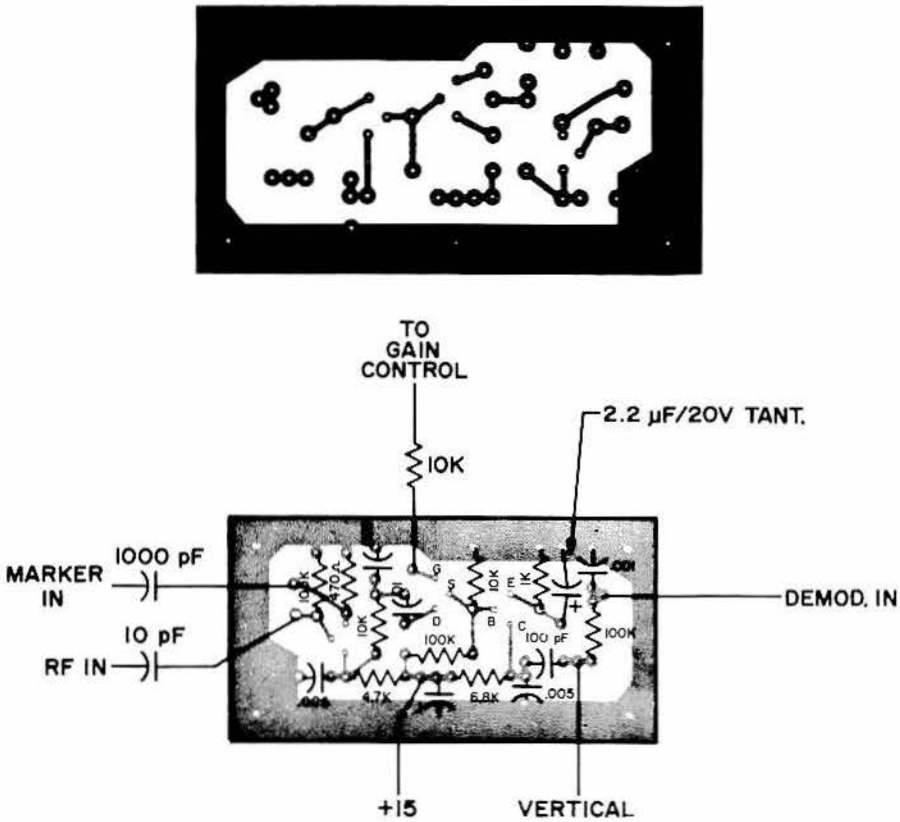
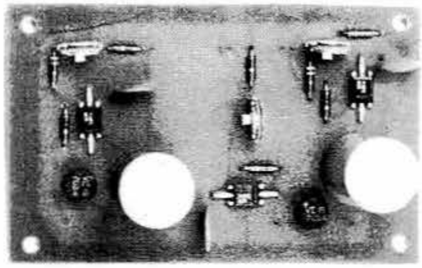


Fig. 9. (A) Foil side of mixer/amplifier pc board. (B) Location of parts on component side.



The power supply pc assembly.

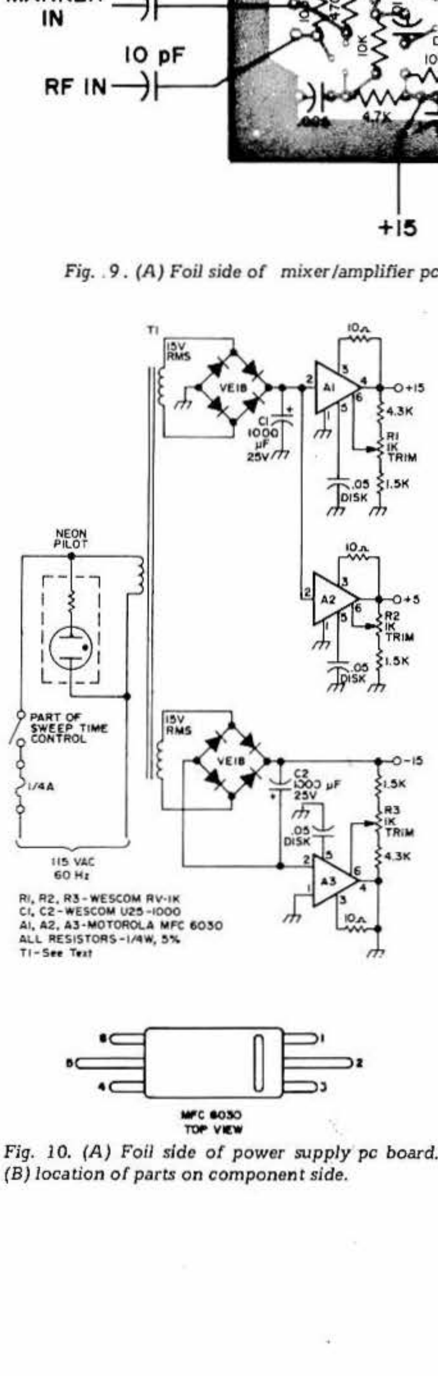


Fig. 10. (A) Foil side of power supply pc board. (B) location of parts on component side.

making the use of small IC voltage regulators ideal. Motorola MFC6030 (plastic) regulators are used in each supply and are overload protected against accidental short circuit. Varo type VE18 molded bridge rectifiers, together with 1000 μF filter capacitors, supply the dc input to the regulators. The +15V and +5V regulators are both fed from the same source. The power transformer was a surplus unit with a 30V CT secondary. The center tap was uncovered and the two leads separated so as to provide two independent 15V windings. A small trimmer is provided in each supply for voltage adjustment.

The pc board for the power supply is 2.6 x 4.1 in. All components but the transformer are mounted on the board. The transformer is mounted directly on the chassis. Relative placement of the various components making up the complete generator can be seen quite clearly in the photo.

Control Circuits

Figure 8 is the wiring diagram for the control circuitry. Note that for CW operation of the generator, a dc voltage is applied to the varactor by way of the Start pot. In order for the dial calibration to be valid in either mode, the dc level applied to the control must be exactly the same as the peak amplitude of the ramp during swept operation. As will be explained in the set-up procedure, the ramp will vary from a starting point of approximately +1.4V and peak at +12V. Resistor R1 in series with the +15V line is selected for a +12V level at the high end of the pot. R2 is selected for a level of +1.4V at the low end. The reason for the offset of 1.4V at the low end is because the pin to which the tuning diode is connected at the MC1648, sits at this level. The source of this bias is the drop developed across two forward-biased junctions within the IC and not from any external source. Once these dc levels have been set for CW with the fixed resistors, the ramp can be made to match by means of the trimmers in the ramp generator circuit.

The rest of the control circuitry is quite straightforward. In position 2 (Swept 1) of the mode switch, positive pulses from the ramp generator are fed to the band switch during the sweep period. When retrace occurs, the pulse drops to zero and the oscillator shuts off until the next sweep starts. In the CW and Swept 2 positions of the mode switch, a steady +15V is applied to the band switch and the oscillator runs continuously.

The final function performed by the mode switch is to route the dc for CW or the ramp for swept operation to the tuning diode. The two fixed resistors are mounted point-to-point behind the panel since all points are readily accessible within every short distances. The fixed resistors associated with the marker gain control are also mounted the same way behind the panel. The switches are ordinary rotary types and the potentiometers are all ordinary carbon controls. The Start and Stop controls as well as all gain controls have linear tapers. The Sweep Time pot is an audio taper type with built-in switch for ac power.

Setting Up the Ramp Generator

For best results, a calibrated dc scope is required to properly adjust the ramp generator. Test points have been provided on the pc board and short pieces of bare wire connected to each of these points make excellent tie points for the scope probe. The

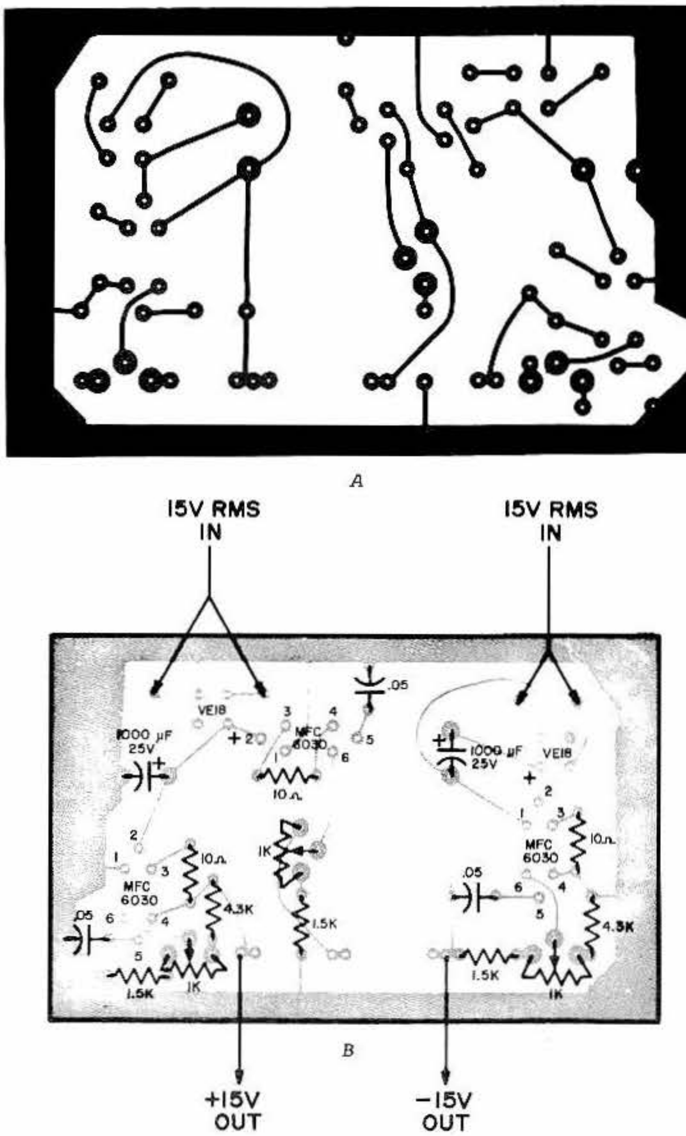


Fig. 11. (A) Foil side of power supply PC board. (B) Location of parts on component side.

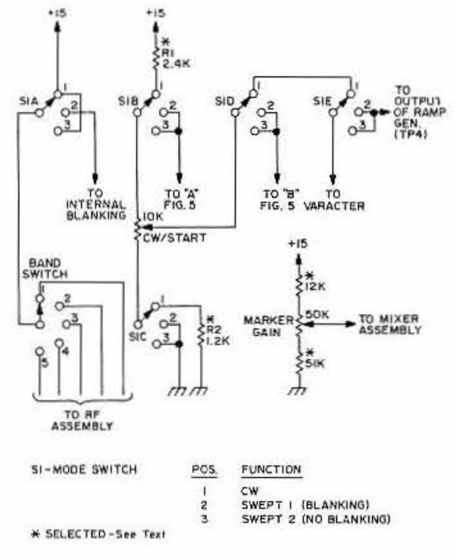


Fig. 12 Control circuit wiring schematic.

circuit may be aligned either before or after installation. The Start, Stop and Sweep Time pots can be connected at the ends of their respective leads if the unit is checked outside the cabinet.

Set all seven trimmers to mid-range. Connect the scope to TP1 and adjust the horizontal for a full sweep of 20 ms. Set the Sweep Time control to minimum resistance and apply power. Some sort of triangular wave should be displayed. Adjust R1 for a 3V p-p amplitude of the waveform. Turn R2 cw until the negative-going portion of the triangle is 20 ms long. Since R1 and R2 interact, you will have to stop occasionally and reset R1 for proper amplitude. Once the ramp is set at 20 ms with the Sweep Time pot at minimum, the slow speed end will automatically be about 5 or 6 seconds with a 1 MΩ pot.

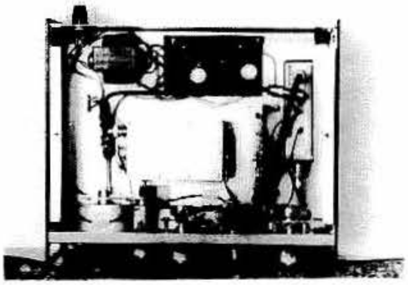
Transfer the scope probe to TP2 where a positive-going ramp should be seen. Set the starting point of the ramp to zero volts by means of R3. Amplitude of this ramp must be 10V. If it is not, go back and adjust R1 slightly until it is. If necessary, reset R2 for 20 ms trace length. As soon as a 10V, 20 ms, zero-based, positive-going ramp has been achieved at TP2, go on to TP3.

At TP3 there should be a negative-going ramp. Once again we require a zero base line or starting point. Adjust R5 to accomplish this. Amplitude should once again be 10V and is controlled by R4. Once you have a 10V, zero-based, negative-going ramp, move on to TP4.

Connect the probe to TP4 and set the Stop control to full cw. The Start pot should be at minimum setting. A positive-going ramp should be present at TP4. By means of trimmer R7, move the ramp up or down until the starting point is approximately +1.4V. Ordinarily the ramp will not go below zero but will flatten out as the positioning control is adjusted. This is due to clipping in the output amplifier. If the ramp generator is going to be used with another type of VCO, the ramp can be set to exactly zero if desired. In our case we can't as explained previously.

Because a substantial amount of capacitance change occurs in the tuning diode up to 12V, the final ramp amplitude is set to 12V by means of R6. Because R6 stretches the signal in a negative direction, R7 will have to be used to reset the base line at 1.4V. Other than for checking tracking between the CW and swept modes, this completes the alignment procedure for the ramp generator.

When the generator is finished, you can check the tracking by observing actual signals at the input to the VCO. Connect the scope probe to the feedthrough capacitor on the VCO assembly that goes to the tuning diode and set the Start control to maximum. Switch rapidly between the CW and Swept 1 positions of the mode switch. The CW input will be a straight line sitting at +12V while the swept input will be a ramp peaking at +12V. Next, turn the Start control to minimum and again compare levels. If the Stop control is also at minimum, both signals will be straight lines at +1.4V. If there is any substantial difference between the two modes, use R6 and R7 on the generator board to make the ramp agree with the dc levels. That completes all phases of the ramp set-up procedure.



This bird's eye view of the interior shows the location of all major assemblies.

Construction

The cabinet used here is one manufactured by Sorensen Electronics in their Mod-U-Line series. These are the most reasonably priced instrument enclosures I've come across so far and I've used them for several projects. This one is a Model MCH-5129 with a CP-129 chassis plate. Dimensions are: 5¼ in. high by 12 in. wide by 9 in. deep.

The 5-step attenuator was picked up surplus from Fertik's Electronics for about \$10. It is well made and designed for 50Ω systems operating up to 1 GHz. It has an integral female BNC output connector on the front face along with four threaded mounting holes for ease of installation. The input connector is a BNC male at the end of a short piece of coax.

All rf assemblies are interconnected inside the cabinet by means of coax cables. This is clearly evident in the photo.

The Start and Stop pots were mounted on brackets behind the front panel so that Jackson Brothers type 4511/DAF reduction drives could be installed for easier tuning. The two circular dials are slightly under 2 in. in diameter and were cut from sheet plastic. While operating in the CW mode, one of these was calibrated in pencil to provide a pattern for the finished product. A master was laid out using Rubylith® film and rub-on numbers. A negative of this was then made using 3M reversing film. From the negative a finished set of dials was printed on aluminum material of the presensitized variety. These were cut out and stuck to the plastic by means of their own pressure-sensitive adhesive backing. The nameplate was made from the same material. The two index pointers are clear plastic with hairlines scored on the inside surface. They are mounted on spacers directly over each dial. All remaining labeling was done with tub-on lettering.

Vendor Addresses:

Fertik's Electronics, 9th & Tioga Sts., Philadelphia PA 19140.

Sorensen Electronics Co., Inc., 418 Queens Lane, San Jose CA 95112.

Wescom, P.O. Box 2436, El Cajon CA 92021.

100 KHZ THIN-LINE PULSE GENERATOR

James Ashe W2DXH

Ordinary 100-kHz frequency standards are usually audible up to a few tens of megahertz. A good one might be usable at 50 MHz. The circuit described here uses a dual NAND gate to generate a 100 kHz signal whose harmonics are usable to 432 MHz or higher. And it can be built without benefit of special instruments and knowledge.

The thin line pulse

One rather surprising result of higher mathematics is that all repetitive signals are composed of harmonically related sine and cosine waves. For example, the familiar square wave is composed of a fundamental frequency, which sets its basic repetition rate, and of odd harmonics only of its fundamental, which contribute to its square corners. If the harmonics' amplitude or phase relationship is upset, the square wave is distorted. This feature makes the square wave very useful for amplifier testing, but its harmonic content is not very good for frequency standard applications.

Now suppose that we start adding up signals of F, 2F, 3F, and so on, phased in so that they all reinforce each other once per cycle. Let's say thay are all the same amplitude. What would we get? See **Fig. 1A.**

The five equal amplitude sine waves peak simultaneously at the beginning of the fundamental's cycle. Everywhere else, until near the end of the cycle, they are more or less out of phase. Trying to see what will happen, we try adding the first two frequencies. **Fig. 1B**, the result, might suggest something to a mathematician.

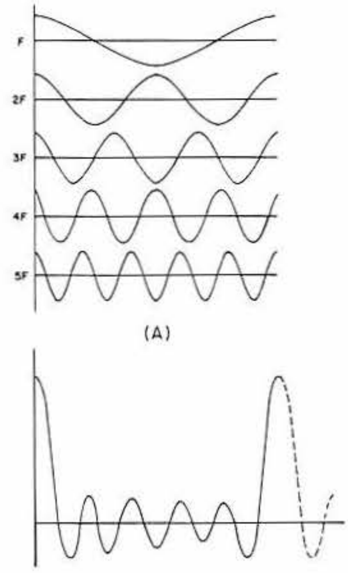
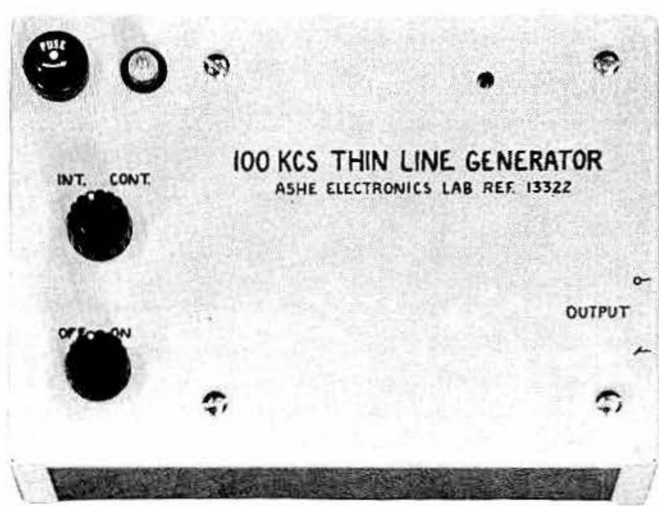


Fig. 1. Five sine waves (A) and the waveform as a result of point-by-point addition (B).

As the number of frequencies is increased, their amplitudes tend to average to zero everywhere except at the beginning of the cycle. Here, they all add up to a short, sharp pulse. It follows that a short, repetitive, one-sided pulse should contain odd and even multiples of the fundamental frequency.

An ideal thin line pulse has infinite frequency content.* No real signal could meet

External view of the 100 Hz thin-line generator.



The finished sweep generator makes a professional appearance.

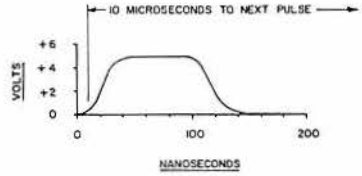


Fig. 2. Real circuit output as seen by a Tektronix 545A oscilloscope. A faster scope shows shorter rise-time and sharper corners.

this spec, but a fast digital IC can produce a very workable approximation. Fig. 2 shows a Tektronix 545A view of the generator output and tests with other scopes indicate the real pulse has better rise time and sharper corners than shown here.

If this pulse is viewed on a low-performance service variety scope, its appearance will be greatly changed. There will be an apparent loss in amplitude, since the pulse occurs and terminates before the slow circuitry can properly respond. The apparent duration is increased, also because of the slower viewing circuitry. And the fast pulse may excite circuit resonances, so that the thin line pulse appears as a damped oscillation. But these problems do not interfere with constructing the generator, because the very simple NAND gate circuitry contains no critical elements or adjustments.

How it works

There are four circuit sections, shown in Fig. 3. A 100-kHz crystal-stabilized oscillator sets the basic frequency, and a dual NAND gate circuit converts the oscillator output to a thin line pulse. A 1-Hz astable generates the output marking signal. A 6 volt dc power source is provided by a voltage doubler zener-regulated supply.

Multivibrator oscillators are not ordinarily very stable frequency sources. But if the oscillator is designed to run slightly below required frequency, and an appropriate crystal is connected between transistor base terminals, oscillations are stabilized at the crystal frequency.

The crystal does not change the multivibrator's style of operation. It synchronizes the astable to its own frequency, by triggering the OFF transistor into conduction shortly before normal RC turn-on. The output is a squarish wave with good fall time, but a long rise time as shown in Fig. 4A.

In passing through the first NAND gate the pulse is squared up and becomes slightly unsymmetrical. See Fig. 4B. A differentiating network, C7 and R11, converts the square wave into the pulses shown in Fig. 4C. These pulses, applied to the second NAND gate, reappear as the thin line pulses shown in Fig. 4D.

Since one CW signal sounds just like another and there may be several in the vicinity of a check point, a marker feature is required. This is provided by the 1-Hz astable, which paralyzes the second NAND gate part of the time. Its base bias resistors are unequal, giving a distinctive duty cycle to the output signal. A switch disables the astable if a continuous signal is required. Fig. 5 shows the output when the second astable is operating: the output is locked in the up condition during half of each 1-Hz astable cycle.

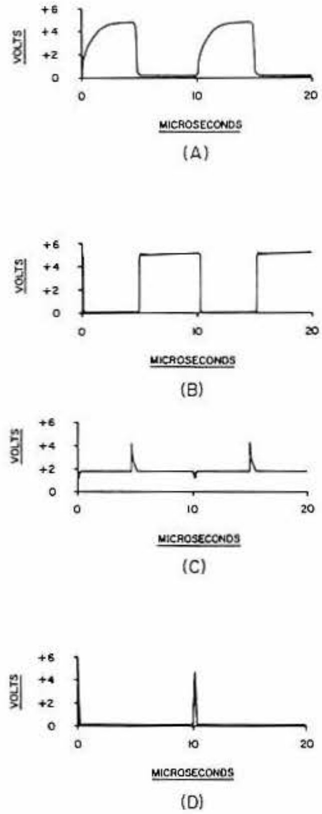


Fig. 4. Signals at four critical points in the generator, as displayed on a Tektronix 545A oscilloscope. They are shown in time coincidence.

Sometimes an astable oscillator will refuse to start oscillating when it is turned on. It does not start because both transistors are in saturation. This reduces loop gain so that available noise cannot be amplified around the loop. It would never start without some strong, outside interference.

A pair of diodes, D1 and D2, provide a reliable remedy. The diodes are arranged so that base bias must come from whichever collector is at the higher voltage. If both transistors are in saturation, their collectors are at perhaps 1 volt, which cannot provide enough base current to keep the transistors in saturation. This contradictory situation does not arise in the real circuit, which starts reliably.

Additional diodes, D5 through D8, appear in the base circuit of the 1-Hz astable. These are protective diodes. The collector swing at turnoff of about 5 volts is conveyed powerfully to the opposite base through the large coupling capacitors C5 and C6. The reverse B-E breakdown voltage of these transistors is not known, so the diodes are provided to prevent the turnoff voltage exceeding 2 volts or so.

DC power for the Generator circuitry comes from a voltage doubler supply based on a low-current filament transformer. Its design is conventional, but a large capacitor, C12, is provided across its output to mini-

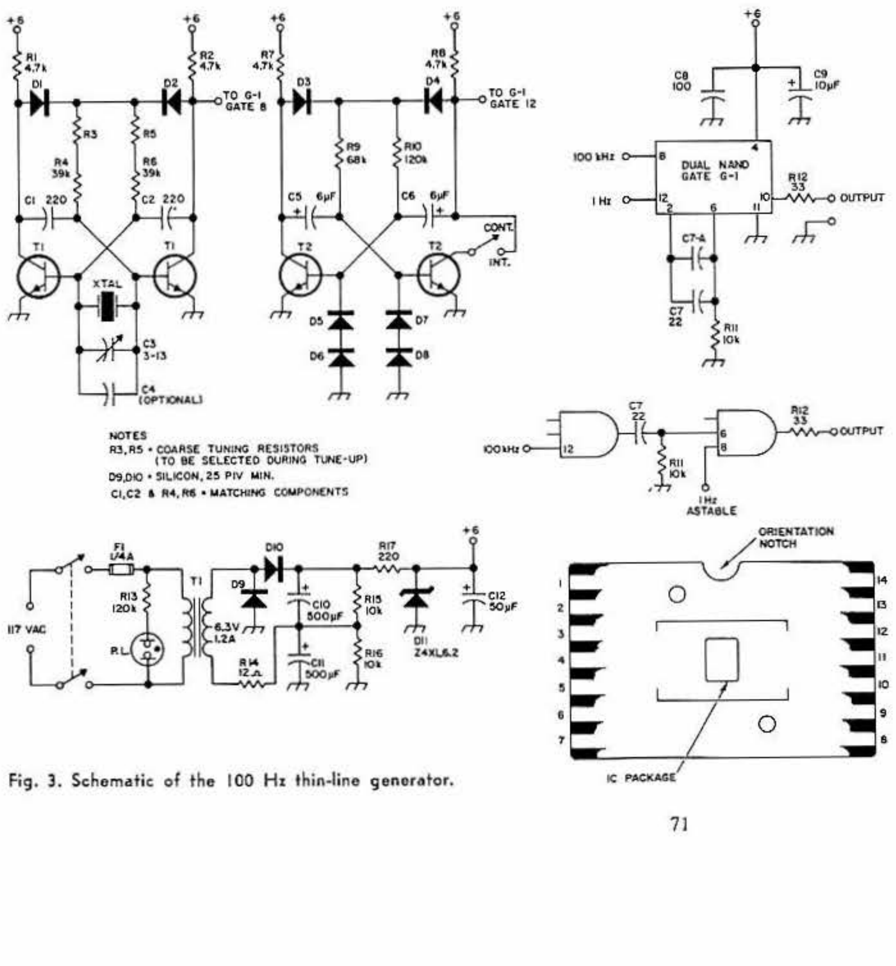


Fig. 3. Schematic of the 100 Hz thin-line generator.

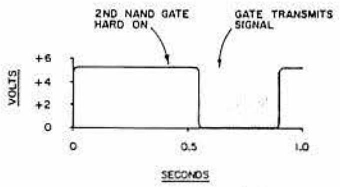


Fig. 5. The second NAND gate locks in its up position part of the time to produce an intermittent output.

mize noise on the supply line. The supply could be replaced with some batteries, shunted by a 50 μF or larger capacitor to absorb transients. The original breadboard ran very well, powered by four flashlight batteries.

Construction

The generator is built in a Premier #PMC 1008 3x5x7 inch heavy aluminum box. Its top cover was refinished in light green enamel, and four ⅜ inch grommets in the bottom piece serve as protective feet.

Inside the box, the 6.3-volt transformer and cheater cord connector are mounted on the left-hand wall. A pilot lamp, fuse, and two switches are mounted on the horizontal panel, at the extreme left. This leaves just enough open space for the two circuit boards which occupy most of the box. Two banana jack output connectors are placed on the right-hand side, just below the panel.

The circuit boards are cut to 4½ x 5 inches, from Vector 3/32 inch pattern A stock and mounted parallel to the panel. The upper board is spaced an inch from the panel, and carries both astable oscillator circuits. The other board is mounted one half inch below, and carries the digital IC and the power supply circuitry. Assembled, the two boards make a sandwich with wiring sides together.

Both boards are mounted on the same four centers. These are through the second hole diagonally inward from each corner. The 1 inch 6-32 internally threaded spacers are modified by adding a short length of 6-32 threaded shaft to one end of each, simplifying assembly.

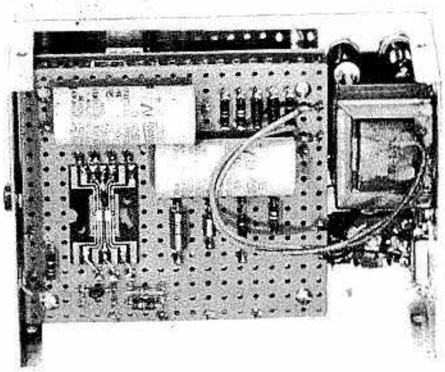
Component assembly on the boards is largely a matter of plugging in Vector T9.4 lugs. The finished product looks much better if some thought is given to facing the lugs in one of two directions. Mounting and transistor holes should be drilled and reamed to size before installing lugs.

The general arrangement puts all wiring on one side of the board and practically all components on the other side. This approach seems a little inflexible but is straightforward and looks good.

Possible board orientation problems may be overcome by working out a handling and wiring procedure that doesn't require constant reference to actual components. A good approach assumes that the board is only turned over an imaginary hinge at its bottom edge, so that top down when one side is up becomes bottom up when the other side is down. This preserves left-right relationships. Another useful convention is that all supply wiring goes to left-hand end of components.

Wiring is carried out one network (plus supply lines; ground lines; interstage lines, etc.) at a time, with prearranged color coding. Bare wire goes for short runs and where there is no chance of a short. Solder each lug when convenient. #22 solid wire fits the T9.4 lugs well, but flexible stranded wire is used for the four lines from one board to the other.

Transistors precede other components into the board, because they are convenient position markers. They are placed in their



Inside the assembled thin-line generator showing the component side of the power supply and IC board.

mounting holes in the board from the component side, and their leads brought to the T9.4 lugs. Then the other components are mounted on the boards. Diode and electrolytic capacitor mounting polarity should be double checked. The T9.4 lugs may need a little bending before they will take a good grip on the components, but no component soldering is done until everything is installed.

Trimmer capacitor C3 is mounted on its tabs just under the top panel. Then a small screwdriver access hole is drilled over it in the panel, before painting, for vernier frequency adjustment after final assembly.

Certain components are matched before installation. An ohmmeter and a capacitor checker will do a satisfactory job of selecting C1 and C2, and R4 and R6, for equal values. These components are chosen alike for best symmetry of the 100-kHz oscillator operation. It might be good planning to leave these components unsoldered until tuning is completed, but everything else can be soldered to the board at this point. Note that the R3 and R5 sites do not get resistors until later.

Two optional capacitor sites are included. These are for C4, an additional and probably unnecessary padder across the crystal; and C7A, which can be added to increase the width of the thin line pulse.

Apparently, the digital IC comes in a specially designed package for testing before use. To mount the IC, solder a ⅜ inch piece of #22 wire in each of the T9.4 lugs carrying supply and signal voltages to the IC. Place the IC between the two rows of lugs, bend the wires against the proper terminals, and solder. No other mounting is required.

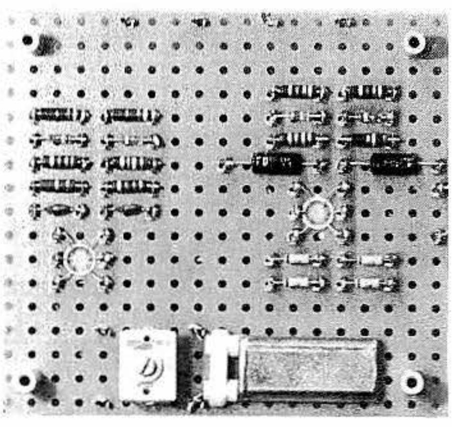
The original breadboard showed a lot of transient noise in its supply circuit. This originated from the IC, which was trying to get big chunks of current to manufacture pulses. Since the IC cannot deliver frequencies not available from the supply lines, very careful bypassing is indicated.

High-frequency bypassing consists of C9, a .01μF disc ceramic capacitor across the IC supply terminals on the wiring side of the board, and C10, a 100 picofarad capacitor soldered directly between supply terminals on the IC. The capacitor leads are provided with spaghetti insulation and placed for minimum open space between the capacitor leads and the IC's supply leads.

Testing before final assembly is very easy, because the odd appearing board layouts go together giving a structure that opens out like a book. The hinge is the four leads between boards. Leave transformer leads long, so that the circuit may be tested well free of its cabinet.

The upper half of the Premier box is prepared by a powerful cleaner which removes its original paint. After thorough removal of the cleaner, the metal is roughened with wet sandpaper, rinsed in vinegar solution and then clear water, leaving a very good surface that does not require priming for excellent paint adhesion. Watch out for greasy fingerprints.

Rustoleum #868 Green applied from a convenient spray can gives a fine finish. Follow instructions on the can. After drying, the fresh, clean enamel will take waterproof India ink, applied with a Leroy drafting pen. When the ink is thoroughly dry, a final coat of Rustoleum #717 Clear finishes the job. The enamel is soft at first, but hardens into a coat durable in normal lab use.



View of the component side of the astable oscillators board.

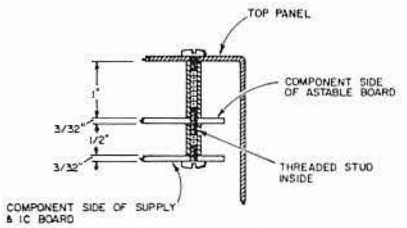


Fig. 6. Mounting dimensions and spacer assembly diagram.

Table of special parts

Crystal: 100 kHz parallel resonant 32 pF. shunt capacitance normally designed quartz crystal.

The following parts were obtained from Solid State Sales, P. O. Box 74, Somerville, Mass. 02143.

- T1 & T2: 2N2060 type dual NPN transistor
- D1, D2, D3, D4: fast point-contact Germanium diodes coded IN59
- D5, D6, D7, D8: fast point-contact Silicon diodes marked S284GM
- G1: surplus digital integrated circuit Solid State Sales type G1. (comes with data sheet)

Tuning up

The generator should be zeroed to frequency before installation in its case. This is a two-step process. First, the 100-kHz astable base resistances are adjusted by choosing resistors for R3 and R5 to bring the oscillator frequency within trimmer range of 100 kHz, perhaps a few hundred cycles high at 15 MHz. Then the trimming capacitor brings the frequency to accurate coincidence with WWV.

To roughly zero the generator, set the trimmer capacitor, C3, at minimum capacitance. Identify WWV on a short-wave receiver, and tune around a bit to familiarize yourself with what's happening in the vicinity. It would be nice if things are fairly quiet.

Then put 4.7k resistors into the astable board at the R3 and R5 sites, turn on the generator, and look around for the signal. Depending upon actual values of C1 and C2, the signal may be on either side of WWV but is likely to be on the high side. If so, try again with resistors one size larger, which will lower the frequency. You should shortly find resistors that bring the frequency near enough to WWV for final zeroing with the capacitor. Verify tuning range on both sides of WWV.

Correct values for R3 and R5 may be approximated very quickly if a good triggered scope is available. Try selecting resistors for a period of 11.4 microseconds with the crystal removed.

Using the thin line generator

A breadboard test showed that (as might have been expected) there should be some way to distinguish generator signals from other CW signals. The continuous/intermittent feature provides the marking, and once the correct signal is located the generator can be switched to "continuous" for accurate work.

At low frequencies, the generator output and behavior resembles a conventional 100-kHz standard. The signal simply is not as strong. A greater difference appears at higher frequencies: the original model yields an audible beat note at 80-MHz from a diode mixer through an inexpensive audio amplifier. And another test shows a usable signal at 432 MHz: the 4,320th harmonic.

Some connection to the receiver or other detector is required. This is a natural consequence of a circuit design that puts the signal where it belongs, rather than spraying it all over the lab. A few picofarads coupling capacitance is sufficient at all frequencies.

Perhaps this circuit can be used for purposes other than a frequency standard. Its moderate amplitude but wideband output should be ideal for detecting changes in receiver sensitivity over a broad tuning range. In fact, with a little decoupling of the input leads and provision of a coax output connector the generator should do well as a stable, reliable small-signal source. A piece of adjustable waveguide-below-cutoff would make an excellent attenuator for work not requiring exact measurements. Another thought that occurs is possible further development by provision of some arrangement for detecting which harmonic is actually being heard.

Chapter VI

Crystal Calibrators

ALL BAND BAND-EDGE MARKER

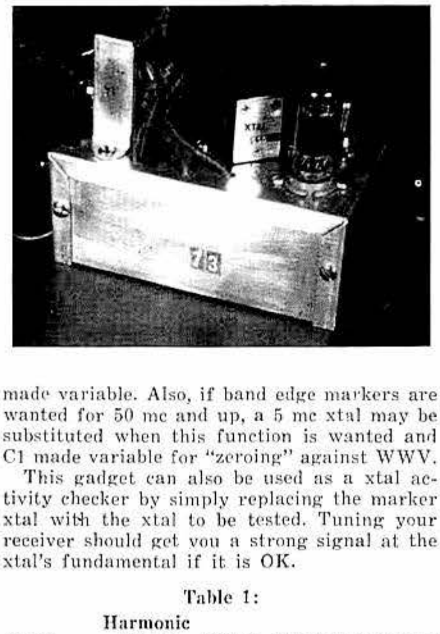
Charles Berner WA2HRZ

This calibrator is complete with its own ac supply, eliminating the need for taking power from the receiver. If ac outlets are at a premium at your shack, the on-off switch and the line plug can be eliminated and the ac line connected across the receivers ac input so that the calibrator comes on whenever the receiver is turned on. A high density selenium rectifier was used and this contributes greatly to the compactness of the unit. The whole thing runs very cool and even after 24 hours operation, still isn't hot.

Wiring isn't too critical, but keep all leads short and direct. Using an octal socket for a xtal holder lets you use the unused pins as tiepoints and is recommended.

A Peterson type Z-2 xtal was used because it has a tolerance of .002%. This is one reason why no provision is made for "zeroing" the calibrator against a standard. The other is that there isn't any such standard as WWV for use. However, if this provision is desired, C1, the 56 mmfd capacitor, connected to pin 1 of the 6BH6 thru the 18K resistor, can be made variable. Also, if band edge markers are wanted for 50 mc and up, a 5 mc xtal may be substituted when this function is wanted and C1 made variable for "zeroing" against WWV.

This gadget can also be used as a xtal activity checker by simply replacing the marker xtal with the xtal to be tested. Tuning your receiver should get you a strong signal at the xtal's fundamental if it is OK.



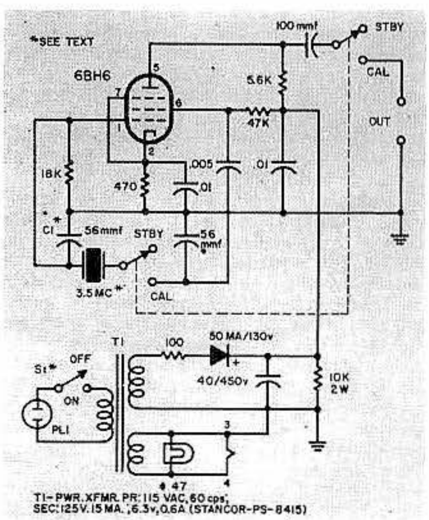


Table 1:

Band	Harmonic 3.5 mc	100 kc	Marker Frequency
80 meters	1	35	3.5 mc
40 "	2	70	7.0 mc
20 "	4	140	14.0 mc
15 "	6	210	21.0 mc
10 "	8	280	28.0 mc
6 "	15	525	52.5 mc
2 "	42	1470	147.0 mc
1¼ "	63	2205	220.5 mc
1¼ "	64	2240	224.0 mc

THE MULTICAL

E. R. Davisson K9VXL

What is the "Multical"? As the name implies, "multi" would suggest several uses, and "cal" might infer a calibrator of some sort.

Well, that's right, but there is slightly more significance to the name. "Multi" is also a short form term used to describe flip-flop circuits known as multivibrators.

By combining the basic characteristics of a free-running multivibrator (astable) with crystal control, you have a simple, stable, virtually-insensitive-to-temperature-changes, crystal calibrator for that receiver you have been wondering about.

The circuit uses no inductors and depends upon the crystal for the proper feedback for oscillations. Temperature stability is partially due to the absence of capacitors.

Transistor stage Q_2 operates with unity gain, whereas transistor Q_1 operates at considerably more gain. Both stages are operating as feedback amplifiers. The harmonic generator diode D_1 is a 1N128. Any general purpose diode may be used.

By using the multivibrator circuit, the waveform obtained is comparatively rich in harmonics and could be used without any further refinements. However, to insure useful harmonics through 30 MHz starting from a 100 kHz crystal, a harmonic generator consisting of R_6 and D_1 shown in **Fig. 1** was added. The capacitors C_1 and C_2 are used strictly for coupling and have no effect on frequency stability.

Crystals from 100 kHz up to 1 MHz may be used in the Multical with no changes. The circuit will oscillate from voltages as low as 2 volts and can be operated safely from voltages as high as 20 volts. This wide range of voltage operation allows the source to be obtained from virtually any place.

Output from the calibrator may be fed directly into the receiver's input, or may be coupled to a short whip antenna. With a whip antenna, close coupling to the receiver's input

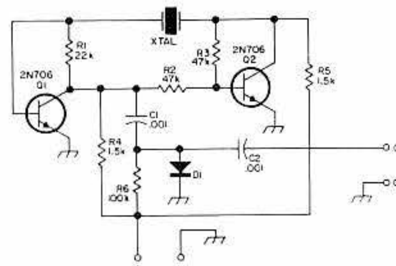


Fig. 1. Schematic of the Multical.

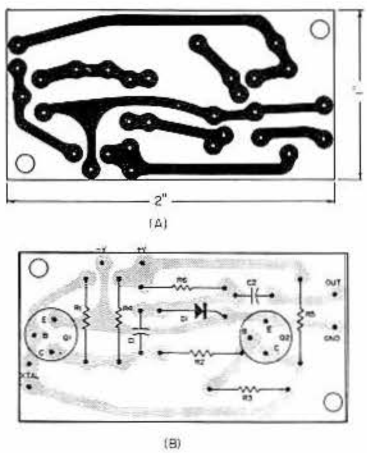


Fig. 2. Suggested printed circuit board layout for the Multical. A gives the copper side, B the component side. A board for the Multical is available for $1 from the Harris Company, 56 E. Main Street, Torrington, Conn.

may be required at higher frequencies. (Especially at the lower voltage levels.)

For the more ambitious builders, **Fig. 2** shows the printed circuit board layout for the Multical. Due to its small physical size (1" x 2"), room can probably be found even in the most compact of receivers. **Fig. 2A** shows the foil side, and **2B** shows the parts placement.

So the next time you wonder about the accuracy of your receiver calibration, give this simple circuit a try and you'll know for sure.

100 KHZ MARKER GENERATOR

W. W. Davey W7CJB

This useful piece of equipment generates usable harmonics from 100 kHz to 225 MHz. It is completely self contained and portable which makes it convenient not only to use in the ham shack, but also in the mobile unit or at a field day location. Its use lies mainly in accurately spotting band edges and 100 kHz calibration points throughout the ham bands.

Most modern day home receivers are equipped with calibrators, but these calibrators are of little use when needed to spot frequencies on VHF and UHF converters or portable equipment.

The generator is constructed in a 2¼ x 4¼ x 1½ inch handi-box. The parts are mounted on a vector board, and the entire unit is powered by one #216 nine volt battery or its equivalent.

Hints on construction First obtain some vector board. The piece I used was cut from the board supplied in a "GE experimenters aid hobbyist kit." The board must be cut to size before construction and will measure 3½ x 2 inches. This will allow room for the 9 volt battery in the end of the handi-box. Make sure the newly cut vector board will fit inside the handi-box before you start mounting parts. It might save a lot of trimming at a later date.

The parts layout is not critical. Components may be arranged as shown in the

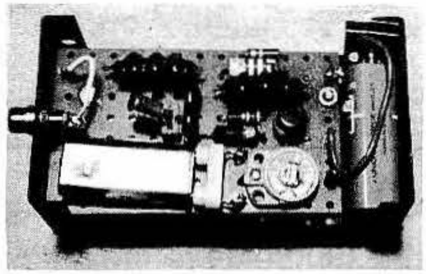
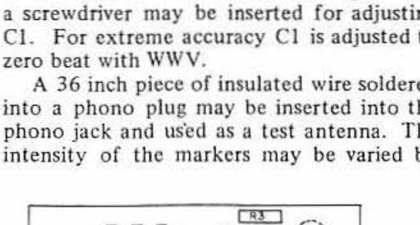


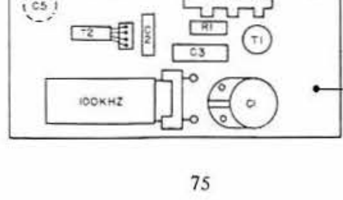
photo or in any other arrangement suitable to the components you may be using. I used sockets for the transistors, as I wanted to be able to experiment to see which transistors from my junk box would give the most output in the VHF and UHF bands. I ended up using the 2N404 for the oscillator and a 2N384 in the multiplier stage. I also found that Japanese 2SA83 transistors which had been removed from the *if* stages of a junked transistor radio, would work equally well in both sockets.

All components are mounted on the top of the Vector board with the exception of C4 and C5. For the most part, wiring can be completed with existing leads on components. The push-in terminals furnished with the GE experimenters kit were used for the battery connections, antenna connection and for mounting the crystal socket. The circuit board can be mounted to the handi-box with three 11/16 inch bushings. This leaves room for a slide switch to be mounted on the cover of the handi-box. Two of these bushings were purposely placed at the end of the board to form a sort of socket to hold the 9 Volt battery. The antenna output connector which is mounted on the handi-box is a switchcraft #3501FP phono jack. A small hole may be drilled in



the bottom of the handi-box through which a screwdriver may be inserted for adjusting C1. For extreme accuracy C1 is adjusted to zero beat with WWV.

A 36 inch piece of insulated wire soldered into a phono plug may be inserted into the phono jack and used as a test antenna. The intensity of the markers may be varied by



moving this test antenna near your receiver antenna lead-in. If you are using a coax lead-in you can couple by drilling a small hole in your coax relay so that the test antenna can be inserted near the relay armature. You will find that most SWR meters provide an easy method of coupling to the center conductor of the coax. As a last resort you can always couple to the receiver or converter antenna coil.

I have made very good use of this gadget to spot frequencies in the 144 and 220 MHz bands. It was well worth the time and effort it took to build it.

ALL BAND FREQUENCY MARKER

Kenneth W. Robbins W1KNI

Crystal controlled marker generators are useful adjuncts in any frequency determining situation requiring high accuracy, such as locating band edges, sub-bands and calibrating receivers. If you've been entertaining thoughts about construction of one, a version is described here which uses the new C/MOS integrated circuits powered by a 9 volt transistor radio battery. And instead of the usual rotary harmonic selector switch, a multi-pin IC connector strip and three test plugs serve as a miniature patch panel to enable various divisions of the reference crystal, with a maximum countdown of 256. "Rocks" from 100 kHz to 4 MHz oscillate readily in this circuit. In this model an FT241 xtal set to 400,000 Hz has been chosen for control and has usable receiver calibration divisions down to 2.5 kHz. The harmonic spectrum extends to at least 160 MHz, the tuning limit of a transistor superregen used in testing. When used in densely

Divide by	Output, kHz
1	400
2	200
4	100
8	50
10	40
16	25
20	20
40	10
80	5
100	4
160	2.5

Table 1.

occupied HF bands, an AM beeper can be switched on as an identification aid.

Referring to Fig. 1, one third of a hex inverter makes up a crystal controlled oscillator and buffer, another third is a slow rate pulser and the two remaining units function in the dividing section. These are all standard circuits described in RCA's COS/MOS Data Book #SSD-203. An emitter follower minimizes loading on the IC outputs, speeds up rise time to increase harmonic content, and provides a low impedance output. The AM

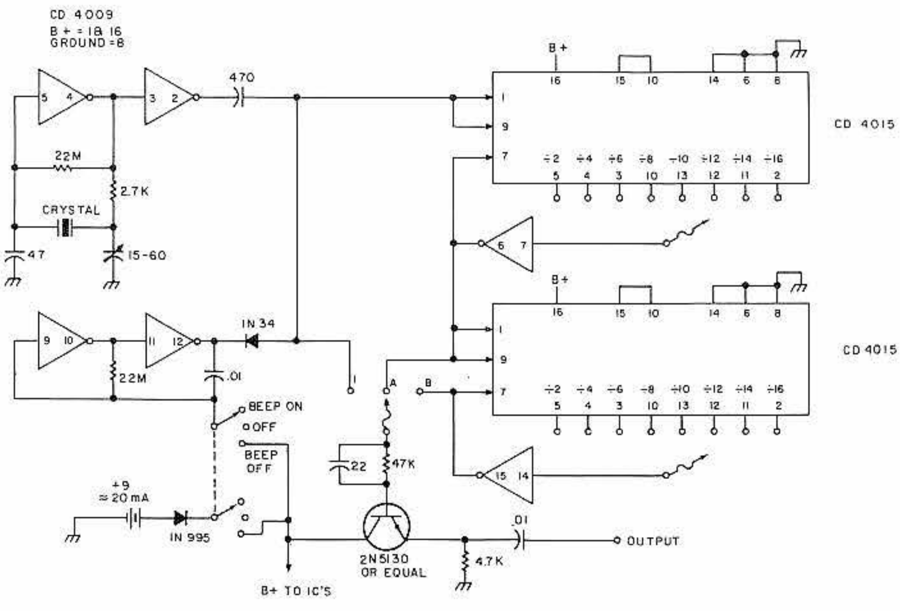


Fig. 1. Schematic.

beeper is a simple clamp that gates rf on or off to following stages.

Photo 1 shows all components mounted on Vector P pattern perf-board that fits inside a Bud minibox. Sleeving 3/8" (10mm) long is slipped over the wire trap terminals of the contact strip to space it up from the board. A DPDT center-off miniature toggle switch acts as one board to panel spacer. Diagonally across from it, a 4-40 threaded rod conducts emitter follower output up through the front panel via a 1/2" (13mm) insulating spacer and plastic shoulder washers. Two regular 4-40 screws and spacers complete the four corner mounting. This spacing allows the contact strip to project partly through a panel cutout so that it is mechanically secure without fastening.

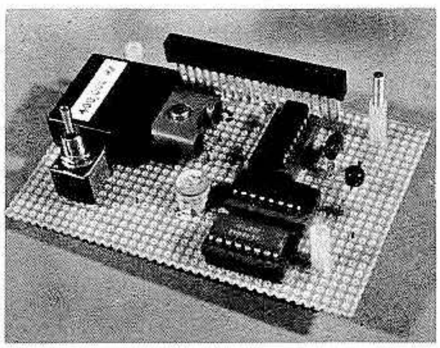


Photo 1.

Photo 2 (completed assembly) shows a stick-on label with patching connection call-outs for various division ratios. If only one crystal is employed, labeling could indicate most used frequencies instead. A typical frequency vs division listing for this model is shown in Table 1. You can easily make up a complete table of all possible ratios, remembering that each CD4015 shift register divides by even numbers ONLY, starting at 2 and ending at 16.

Uses to which a marker generator may be put have been described before: i-f alignment, BFO, scope linearity, etc. A type that divides down to the audio range like this one is especially useful in checking superhets. A

1	CD4009	1	15/60pF trimmer
2	CD4015	1	.01 uF
1	1N34	1	xtal; see text
1	1N995	1	xtal socket
1	2N5130 or equiv.	1	Alco #MST205P switch
1	2.7k	1	Bud #CU-2115HG minibox
1	4.7k	1	Vector #44P29-062 perfboard
1	47k	1	#216 battery
2	22M	1	Battery connector
1	22pF	3	16 pin IC sockets
1	47pF	3	Augat patch pins or equiv.
1	100pF	1	20 pin contact strip
1	470pF		SAE #Series 7000

Table 2. Parts List.

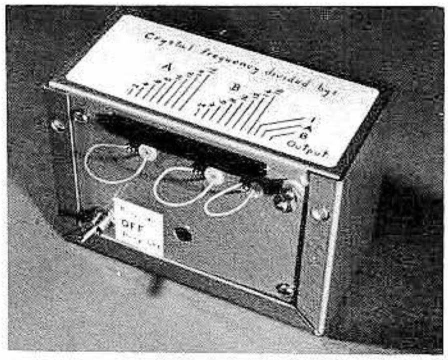


Photo 2.

very broad and flat spectrum of overlapping signals is generated and an audio tone will be heard no matter where the set is tuned. If its tracking and sensitivity are top-notch, the S meter will hold steady over the tuning range. Tracking adjustment amounts to tweaking for maximum meter reading or loudest audio tone. Then patch for 100 KHz markers and check calibration. It's a lot faster and easier than using a conventional signal generator.

POOR MAN'S UNIVERSAL FREQUENCY GENERATOR

John Schultz W2EEY

As precise frequency control and measurement becomes more and more a part of the amateur radio game, the need develops for test instruments that deliver a wide range of both rf and af signals of high accuracy. It would be ideal if everyone could have a frequency counter and a synthesizer type rf and af generator but that is hardly the case. Most amateurs must utilize their basic station gear along with selected accessory items to test out and adjust equipment. This article describes a very useful accessory item that for a modest cost goes a long way toward having some of the expensive test equipment just mentioned. The item to be described is somewhat like a grid-dip meter in that it is basically a simple type of oscillator but as one gets to know and use it, new uses for it are found and its versatility constantly expands.

Circuit Description

Figure 1 shows the circuit diagram of the test generator. Basically, it consists of a string of SN7490 decade counters which are used to divide down a selected input signal by a factor of 10 or 2. The input signal can come from a 1 MHz master oscillator, a special crystal oscillator for externally used crystals or from any external sine-wave source. The special crystal oscillator which uses a SN7400 will operate with almost any basic or overtone crystal in the hf range. It can be used for crystals in the low frequency and lower VHF range also by a simple

modification. One gate of the SN7400 crystal oscillator is used to drive a LED which will indicate that the crystal is oscillating so it serves as a crystal activity indicator as well. When an external sine-wave source is used, it is first coupled through a SN74121 multivibrator. This stage squares off the sine wave so it can better drive the subsequent frequency divider chain.

The frequency divider chain is fixed, although one could easily switch the individual SN7490 units to divide by different ratios when desired. This should be obvious by noting the wiring of the divide by 2 SN7490 with that of the divide by 10 units. However, the variety of frequencies which can be generated then with different input sources becomes confusing and more than would normally be needed.

The fixed divider chain follows the sequence: divide by 10, divide by 2, divide by 10, divide by 10. A separate branch after the first divide by 10 unit goes through two other divide by 10 stages. In the case of the divider chain being driven by the 1 MHz master oscillator, this results in the following output frequencies being simultaneously present: 1 MHz (basic oscillator output), 100 kHz, 50 kHz, 10 kHz, 5000 Hz, 1000 Hz and 500 Hz. With any other frequency input source you can easily calculate what frequency outputs the divider chain will bring in both the rf and af regions. Many surplus crystals will produce interesting frequencies of high stability in the af region that can be used for test purposes.

When using the special crystal oscillator, the LED will glow to indicate that oscillation is taking place. As shown with a 150 pF capacitor from one side of the crystal oscillator circuit to ground, the oscillator will work satisfactorily with hf crystals. Its range of oscillation can be extended to lf as well as high frequency overtone crystals by changing this capacitor. The value of capacitor required in picofarads is 500 divided by the frequency of the crystal in MHz. This value need, however, to be only approximate unless you require an absolutely square wave output from the unit.

When using the multivibrator input about a 1½ to 2V peak input, either sine-wave or approximate square wave is required.

Construction

The whole unit can be constructed on a piece of perforated board about 3 x 2 in. and made completely portable if powered by a 4½V battery (Burgess No.532) or just three D cells in series. This arrangement does not provide the absolutely best stability for the 1 MHz master oscillator but unless you intend to use the unit for marker frequency generation in the VHF range, it is a perfectly satisfactory arrangement. Alternatively, one could power the ICs from any standard 5.5V regulated supply used for IC digital circuitry.

I constructed my unit for battery powered operation and enclosed the unit in a small aluminum mini-box. The output of each divider was brought to a pin jack on the front panel of the unit.

One simple way to wire the relatively small number of ICs involved is to purchase perforated board which has hole spacing to fit standard DIP and preferably with a copper pad still left around each hole. The ICs are then placed on the board and the appropriate pins which either go to ground or to the 4.5V line bent in different directions. The ground line is run along one side of the IC and the 4.5V line along the other side and bare wire used to connect the appropriate pins to either line. Figure 2 illustrates the wiring for one of the divide by 10 ICs. When one starts this process on the board, it will be surprising how fast the wiring is completed. Individual insulated wire jumpers are used to make the input/output connections between ICs. The wiring is not critical and using a receiver to hear the markers, or an audio amplifier for the lower frequency outputs, one should be able to determine quickly if the circuit is working. The frequency of the 1 MHz master oscillator may be brought exactly on frequency using the 25 pF trimmer in the circuit and checking against WWV with a harmonic of the oscillator or by using a counter.

Applications

As I mentioned before, the applications that you can find for the generator really begin to unfold only after you have had it around the shack for awhile. Some of the applications would be:

1. A frequency marker generator for receiver calibration. The markers are usable up into the VHF range.

2. To extend the range of present rf or af signal generators into lower frequency ranges than they presently cover.

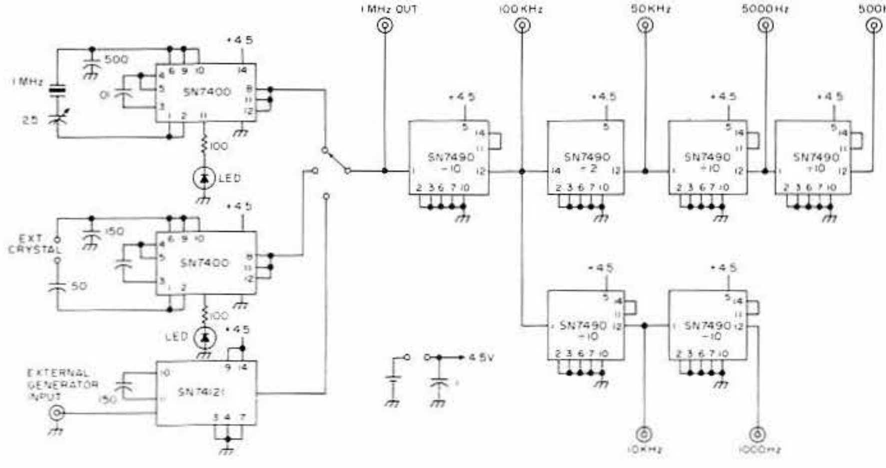


Fig. 1. Diagram of universal frequency generator. Output frequencies shown are for using 1 MHz oscillator.

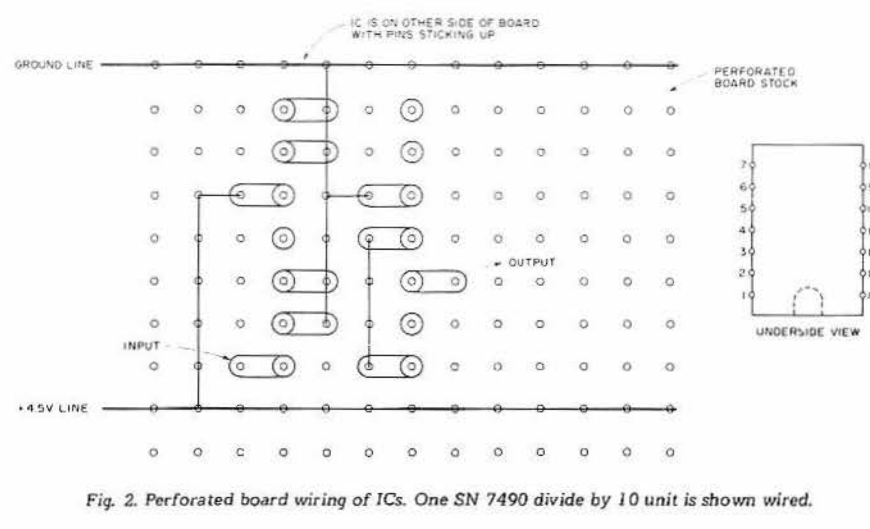


Fig. 2. Perforated board wiring of ICs. One SN 7490 divide by 10 unit is shown wired.

3. To perform stability checks on high frequency variable oscillators. The divider chain will always perform precisely and you can monitor the change in frequency of a higher frequency oscillator with a stable low frequency receiver.

4. A frequency generator to generate precise rf or af square wave signals at any frequency desired by choosing the proper crystal.

5. A crystal activity checker.

6. By taking two or more of the simultaneous outputs together via mixing diodes and a series tuned circuit resonant at the desired frequency, you can also mix the divider outputs to generate a variety of intermediate frequency outputs.

CALIBRATE THAT CALIBRATOR

Mitchel Katz W2KPE

Most modern receivers and transceivers in use today rely upon a 100 kHz crystal oscillator to calibrate the tuning dial. While some of the calibrators are built in, others come as outboard accessories. In any event the operation of each is the same.

By this time we all probably know what "zero beating" is. The 100 kHz oscillator in order to serve as a calibrator must be "zeroed" to some standard frequency such as the WWV carrier frequency on 5, 10, 15, 20, etc. MHz. With a CW or AM receiver, we can very easily tune through the zero beat point. On SSB receivers because one of the sidebands is missing we can only hear the one side as we approach zero. The other side of zero is greatly attenuated and may possibly not be heard at all. To further complicate matters for us in trying to calibrate the 100 kHz oscillator, as we can only hear down to about 20 Hz, we can't zero in any closer than this. Leaving the receiver at this point, we next turn on the 100 kHz calibrate oscillator. After a suitable warm up period, we turn the tune control of the oscillator and again adjust for a zero beat condition against the WWV frequency. With this method of calibration we have several possible sources of error. First in zeroing WWV with the receiver beat frequency oscillator and then zero beating the 100 kHz calibrator against the bfo. Each of these adjustments is limited to the lower limit of our hearing range, as well as the fact that we are obtaining the zero beat at a relatively low i-f frequency.

A more accurate method of calibrating the 100 kHz oscillator will now be discussed. After the receiver and calibrator oscillator have been warmed up for about 30 minutes, tune in WWV on a frequency that produces a fairly good, steady signal. Adjust the tuning for maximum reading on the S-meter. Having tuned in WWV, turn *off* the beat frequency oscillator. Now turn on the 100 kHz oscillator that is to be calibrated. If a harmonic of this oscillator is fairly close to the WWV frequency, a beat note will be heard. At this time adjust the calibrator "crystal tune" control and the S-meter will start pulsing from a maximum to a minimum value. The closer you get to dead center the slower the pulsing action will become. It is fairly easy to come down to 1 pulse per second with this method. If your receiver doesn't have a meter, you can also hear this pulsation very clearly. In any event you would always tune for the slowest pulse rate.

Note that with this method we have adjusted the calibrator frequency harmonic directly to the WWV carrier rather than to a low i-f. We have eliminated one zero beating step, and this, together with the fact that we are obtaining the zero beat at a much higher frequency, will provide greater accuracy.

Having described the method, here are a few points of general interest:

1. Before attempting any calibration let the equipment heat up for at least a half hour to stabilize.

2. After tuning in WWV, wait until the 400 Hz modulating tone goes off before adjusting the calibrator. If not, you may find later that you zero beat the 400 Hz instead of the carrier frequency!

3. The levels produced in the receiver by WWV and the calibrator oscillator should be about equal to produce a good beat between the two frequencies.

4. Use the highest WWV frequency that will produce a good, stable signal in the receiver. Certainly a 1 pulse per second beat at 20 MHz will provide greater calibration accuracy than 1 pps beat at 5 MHz or better yet than 455 kHz! The accuracy will be considerably greater and it is no more difficult to come by.

A SIMPLE FREQUENCY DEVIATION METER

John Reinartz K6BJ

A frequency-deviation meter allows one to read the deviation plus or minus that a received signal is off frequency. Depending on the meter range desired and used, a deviation of ten or less cycles can be read either high or low. Such a device is especially useful when used on MARS nets or when frequency checks are desired of any incoming signal and the answer must be in cycles low or high of a desired frequency. Those grinding their own crystals or desiring to compare crystals will find this device especially useful.

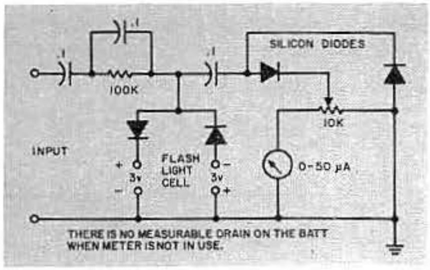


Fig. 1

Two fundamental circuits were investigated, one using diodes only and the other using transistors only. These are shown in Fig. 1 and 2 respectively. A 0-50 microampere meter should be used for the diode type and a 0-1 milliampere meter will serve nicely for the transistor type, although a 0-50 or 0-100 microampere meter will also serve nicely in the transistor type frequency-deviation meter system. Silicon diodes were used for the diode type and 2N123 for the transistor type. An input voltage of 25 is needed for the diode type and 7 volts or less for the transistor type depending on the meter sensitivity, being 2 volts when a 50 microampere meter is used.

Whatever scale reading is desired, be it 250 cycles low or high or 500 cycles low or high, the meter cover is removed and new figures are added below the meter scale with a zero in the center of the scale and maximum readings at each end of the scale as appropriate. Pencil markings will do. The 250 cycle can be read to 10 cycles per division and the 500 cycle scale can be read to 20 cycles per scale division. Each can be read to half these values or 5 and 10 cycles respectively.

In use, you set your frequency meter, LM or 221 either 250 cycles or 500 cycles lower

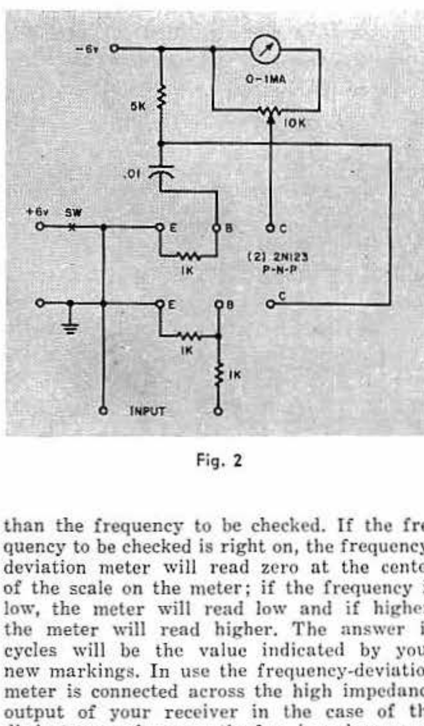


Fig. 2

than the frequency to be checked. If the frequency to be checked is right on, the frequency-deviation meter will read zero at the center of the scale on the meter; if the frequency is low, the meter will read low and if higher, the meter will read higher. The answer in cycles will be the value indicated by your new markings. In use the frequency-deviation meter is connected across the high impedance output of your receiver in the case of the diode type and across the low impedance output in the case of the transistor type.

In those cases where a definite frequency will be under observation, it will be found advantageous to grind or obtain a crystal that is adjustable to 250 cycles low or 500 cycles low, as appropriate, and to use it in the transistorized oscillator shown in Fig. 3. Any crystal holder that has an adjustable air gap will do. Some of the TCS surplus crystal holders have a three point adjustable top plate and are about the best obtainable. Since your

best and probably only method of adjusting the crystal is by the use of your LM or BC221, be sure that your frequency standard is accurate. It is best to use the low frequency position and with the 1 mc crystal switch on, tune the meter to that portion of the desired frequency less the mc part. For instance, to set the LM for a reading of 2,732,000 cycles, set the LM on the low frequency for 732,000 cycles or 732 kc. The 1 mc crystal will furnish the mc part of the reading. In my case I set the LM to 731.5 kc and adjust the crystal to that

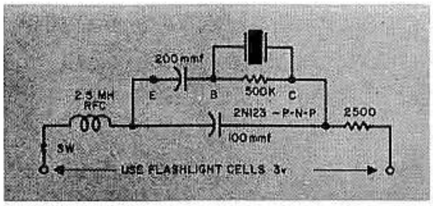


Fig. 3

frequency in the adjustable TCS holder. The transistorized oscillator holds the frequency to such a close tolerance it has not been necessary to make adjustments in weeks. A hand held push switch connected into the positive battery lead allows the oscillator to be turned on as needed to check the frequency of a MARS station on 2732 kc to an accuracy of plus or minus 10 cycles of that frequency. The frequency-deviation meter is of course checked against the 440 or 600 cycle tone of WWV, no other check is necessary since the scale is linear.

Chapter VII

GDOs

THE INDICATING OSCILLATOR

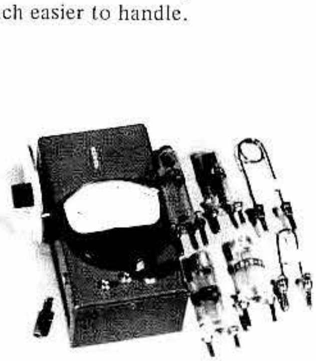
Ken Brown KH6AF

Relatives of this little gadget have been around a long time! Even the transistorized versions, which usually leave something to be desired. With an FET, however, we are back in business as with tubes, but with many advantages.

The range of this oscillator is fantastic. That is, without any circuit tricks or special handling. The low frequency end was carried down to the 1 MHz in order to cover the lowest ham band. The high end takes care of 250 MHz easily. This can be extended with a little more effort.

Use of a field-effect transistor (FET) allows operation more nearly like the tubes with which we are, perhaps, more familiar. However, we are not tied to the power lines, which alone makes it worthwhile.

A 2N4221 FET was used in this indicating oscillator. Very likely other FETs will work also. The MOSFETs also should be as good, if not better. The new ones with built-in diode protection would be much easier to handle.



Standard banana plugs spaced ¾ in. make ideal bases for the coils. The lower frequency coils are wound on polystyrene forms.

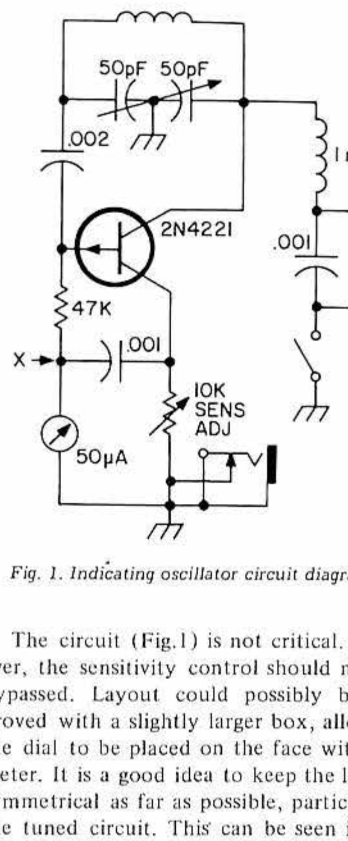


Fig. 1. Indicating oscillator circuit diagram.

The circuit (Fig.1) is not critical. However, the sensitivity control should not be bypassed. Layout could possibly be improved with a slightly larger box, allowing the dial to be placed on the face with the meter. It is a good idea to keep the layout symmetrical as far as possible, particularly the tuned circuit. This can be seen in the photo of the inside view. The box used was an LMB 532 EL with the cover reversed to allow for coil mounting insulator (polystryrene or other good rf insulating material). The meter should be a 50 μA movement; otherwise, a meter amplifier such as the one shown schematically in Fig. 2 will be necessary. This is no problem, as there is room for this amplifier on the circuit board.

A thumbwheel from a BC-375 tuning unit could be used very nicely as a dial. Three sides have been left clear for ease in placement of unit when in use. Plug-in coils makes for easy bank change and application to the job at hand. Standard-spaced banana pins allow for use with other accessories. Use 5/8 in. polystryrene tubing and stud-type banana pins.

A dual banana plug can be used during construction for setting the spacing accurately. The coils shown have the pins wired in place for stronger mechanical assembly. Drill a hole for about 24 AWG copper wire on each side of the pin studs which will lie along each side of the poly tubing. Use a number 59 or 60 drill. One wire is enough on each pin. Form a hairpin with about an inch of wire, push it through the drilled holes from the outside. Now twist tightly with longnose pliers, cut it off short, but not so short as to allow the wire to untwist! Then apply several coats of liquid "poly" cement. Be sure to move the coils frequently during the hardening period to make sure the liquid "poly" flows evenly over the stud and forms a slight fillet with the tube. Epoxy doesn't seem to work well with polystyrene. Neither Allied nor Newark list liquid polystyrene any longer, but your neighborhood hobby shop should be well stocked.

The lowest frequency coil (number 1, 0.95–2.2 MHz) was made from a Miller

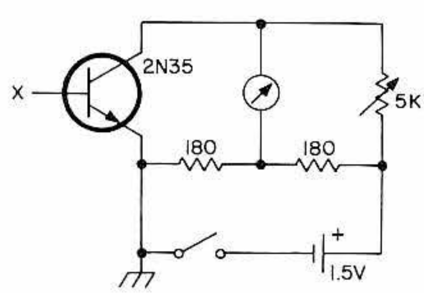
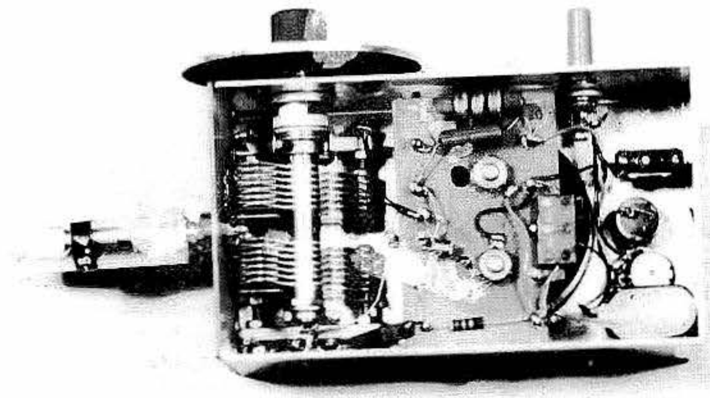


Fig. 2. This meter amplifier will increase the level of the signal so that a less-sensitive meter than 50 μA may be used.



Interior view of oscillator with coil attached shows construction of the author's version.

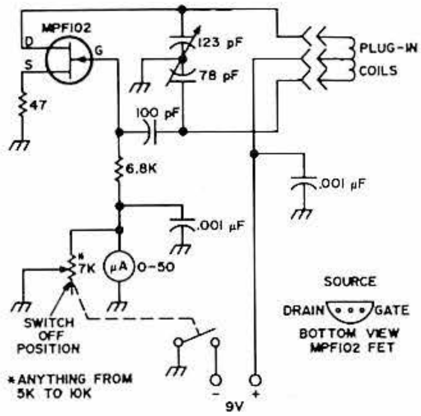


Fig. 1. Schematic diagram of the little gate dipper.

951 ferrite 0.5 mH choke with 6 or 8 turns removed – just enough to slip inside the poly tubing. Some reaming may be necessary. The number 2 coil (2.2–5.4 MHz) was made from a Miller ferrite antenna unit with the slug permanently installed in the top end and all lugs and mounting hardware removed. This coil was also mounted inside the poly tubing. The number 3 coil (5.4–13.5 MHz) consists of 32 turns of 28 AWG enameled wire, close-wound on the outside of the poly tubing. All coils are 2½ in. long with windings as near the end as practical. The number 4 coil (27–50 MHz) consists of 10 turns of 24 AWG enameled wire, close-wound. The number 5 coil (45–100 MHz) consists of 2 turns of 14 AWG enameled wire, self-supporting. The number 6 coil (60–270 MHz) is one hairpin loop 3/8 x 1 in.

A jack is provided for headphone use. The screwdriver-adjusted miniature pot is for zero adjustment of the meter amplifier. It can be seen in the photograph.

THE LITTLE GATE DIPPER

John Aggers W5ETT

Possibly you now own a grid dipper, but is it small, easy to handle, and cordless, making it completely portable? If not, you will want to build this gate dip meter. The cost is extremely low – only about $7. All parts are readily obtainable and construction is simple. The plug-in coil forms, using battery plugs and polystyrene tubing, are easy to make.

The Circuit

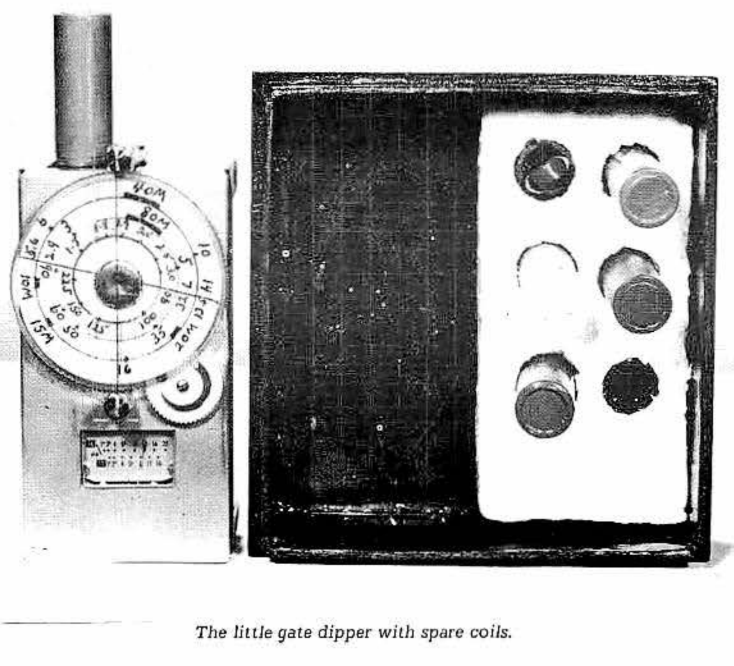
An MPF 102 FET is used in a modified Colpitts circuit. Except for the #1 coil, where a choke is used, the B+ is fed to the centertap of the coil. This is necessary to obtain a fairly constant gate current as the oscillator is tuned to its end frequencies. Drain current varies from 4 to 1 mA proceeding from 225 to 1.7 MHz. At the same time the gate current varies from 20 to well over 50 μA.

From this, it is apparent that the stronger the oscillations the smaller the drain current and the larger the gate current. In gate dip operation, as power is drawn from the oscillator the drain current will increase and the gate current will decrease or dip.

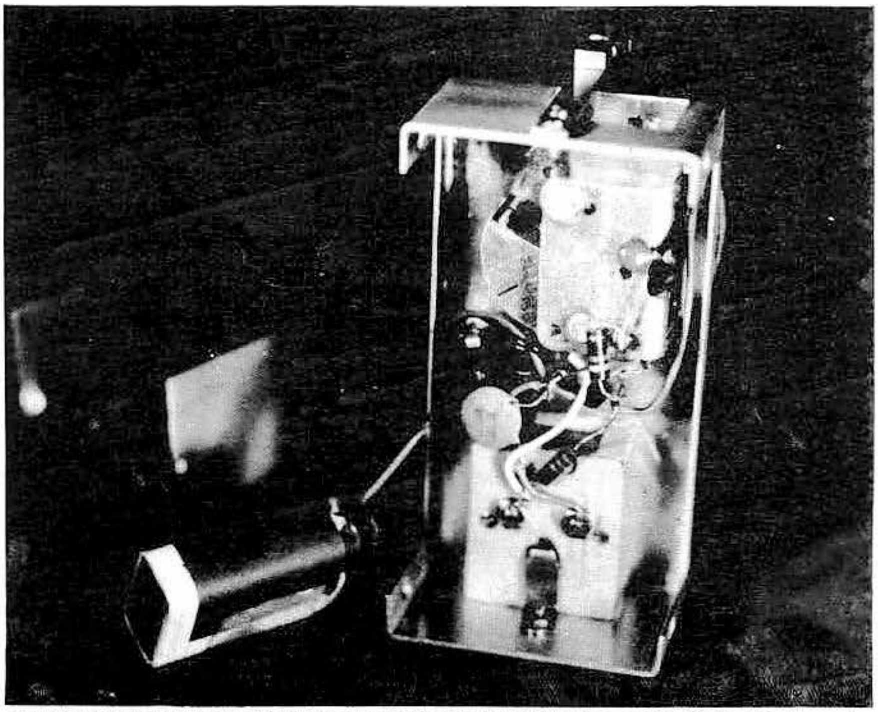
Limited wavemeter operation, obtained by switching off the B+, is accompanied by a slight shift in calibration. When the circuit picks up rf, the FET suddenly goes into oscillation using the rf as its battery. Thus, the amount of rf picked up must be large enough or there will be no oscillation and no meter indication. However, despite these deficiencies, it is still considered a useful mode of operation and for that reason has been included. It is only necessary to wire the sensitivity control so that the resistance is maximum when the switch is in the off position.

Construction

A natural finish aluminum minibox (4 x 2-1/8 x 1-5/8 in.) is used for the meter case. The variable capacitor came from an old transistor radio and measured 1 3/8 x 1/2 x 1 in. The shaft was already squared and tapped for a small screw. Since those listed in the catalogs have a plain or flat shaft, you will have to use a collar with setscrew, or drill and tap the shaft. The trimmer capacitors are not used and should be removed.



The little gate dipper with spare coils.



Meter is held against the front panel by a small bracket. The FET is the small black object in the center.

To make the coil socket you will need three pin receptacles from an octal socket, two pieces of 1/8 in. Plexiglas approximately 7/8 x 3/4 in., and one battery plug for a pattern. The pins of the battery plug form a triangle. I shall refer to the holes at the base as the outside holes. Drill holes in one piece of plastic to match the pins of the battery plug. Match the two pieces of plastic, clamp in a vise, and drill the two outside holes in the second piece. Bend the lug part of each socket pin to a right angle. Slip one over each outside pin of the battery plug. Using this as a jig, solder the lug portions to the stators of the variable capacitor. Remove the plug, and the pieces of plastic should fit down over the variable capacitor. The lug part of the center socket pin is brought out between the two layers of plastic.

File a small notch in the bottom piece to accommodate the lug. Before cementing the two pieces together and to the frame, make each hole slightly larger than the diameter of the socket pins. This will allow for expansion when the plug is inserted.

The dial is made of 2-1/4 in. diameter 1/8 in. Plexiglas. To give the dial a rough edge, for good thumb traction, I heated an old gear wheel and rigged up an arrangement to rotate the dial against it. The gear should have rather coarse teeth and rotate with the dial, or you will create flat spots.

The variable capacitor can now be mounted in the case. Position it so that the top and sides of the dial will be just about even with the edges of the case.

The dial marker is mounted on square aluminum posts. The top post (2 in. long) has 1½ in. of its length filed down to a 1/8 in. thickness to reduce its bulky appearance. To make the hairline, scribe a line in a ½ in. wide piece of plastic and fill in with a ballpoint pen.

The sensitivity control I used was already prepared for the knob shown. If you don't have one like it, use a dime-size pot and a setscrew knob. Any resistance from 5 to 10 kΩ will be fine.

Keystone light meters are available from Olson Electronics in a package of five ($3.99) or Transistors Unlimited Co. (75¢ each). Some modification of the meter is necessary. Remove the light cell and series resistor. Drill two holes, spaced ½ in. apart in the back of the case to pass 4–40 machine screws for easy soldering, make sure the heads and nuts are clean and free of any nickel plating. The screws should be filed even with nuts in order to make room for the battery. Solder the leads from the meter movement to the terminals, but be quick because the plastic case tends to melt in a hurry.

Wiring is just a here-to-there proposition, requiring no terminal boards or terminal lugs. The FET is soldered in place supported by its own leads. With reasonable care you should not damage it. A battery holder was found unnecessary; however, it is a good idea to wrap a layer of tape or stiff fiber paper around the battery to prevent the metal case from shorting out the meter terminals.

Coil Construction

Figure 2 and the photo give the necessary dimensions and show the parts needed to make the coil forms. The battery plugs are listed in the catalogs to fit #482 and

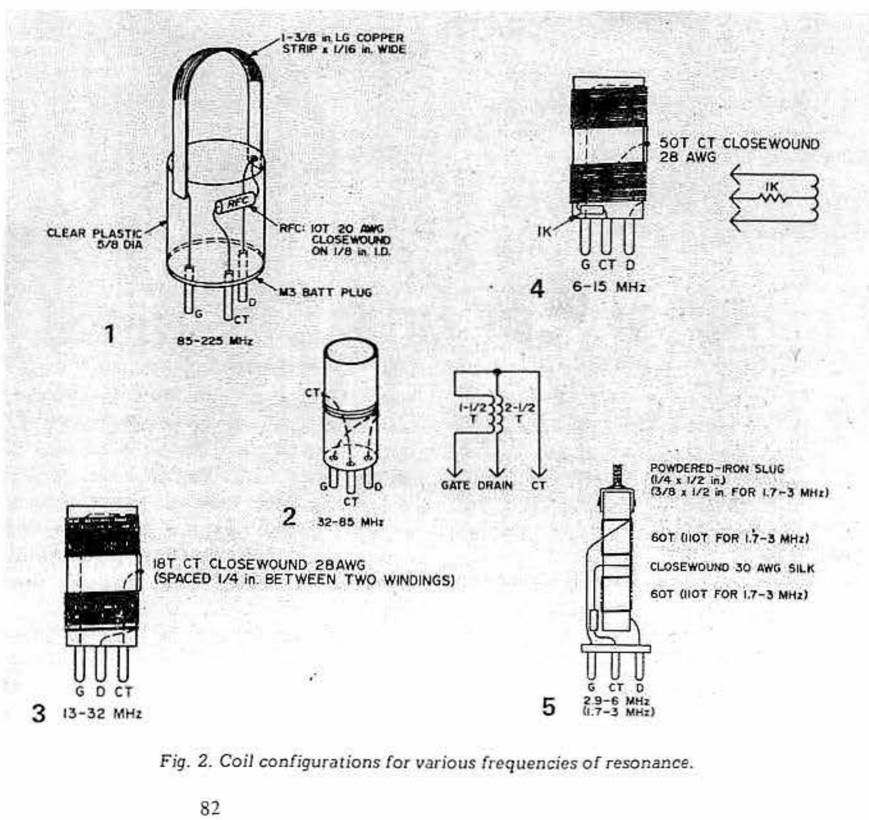


Fig. 2. Coil configurations for various frequencies of resonance.

M3 batteries. The center pin should be filed slightly shorter to make the plug seat evenly in the socket. While you are at it, file the nickel plating from the ends of all plug prongs. This will make for easier soldering.

Complete coil information is given in Fig. 2. However a little explanation may be in order. The irregular method of winding the #2 coil is necessary to reach 85 MHz and still maintain oscillation. With 4 turns close-wound the highest was too low. With the 4 turns spaced, oscillation ceased at the highest frequency. The 30 AWG silk wire was taken from a TV flyback transformer. The resistors in the centertap of the last three coils improve the meter's sensitivity slightly. They are mounted right next to the coil winding. With a slight groove filed inside the insulating sleeve, it should slip over the resistor.

The #6 coil is layer-wound as space permits and scrambled wound the rest of the necessary turns. The top winding of all coils should end near the very edge of the coil form. This will make for easier coupling to a tuned circuit. After the coils are checked out the insulating sleeves may be glued to the plug base.

Allow the glue to dry for several days before plugging the open ends of each coil with a small cardboard disk. The coils are painted with colored lacquers. Colored paper between the coil and the insulating sleeve will probably work just as well.

Calibration

For calibration purposes, you will need another indicating oscillator or dip meter. Operate it in the diode or wavemeter mode and loosely coupled to the gate dipper. I calibrated only 5 points on each scale plus any ham bands which appeared. Remember the dipper is not a frequency meter but something to get you in the ballpark.

Conclusion

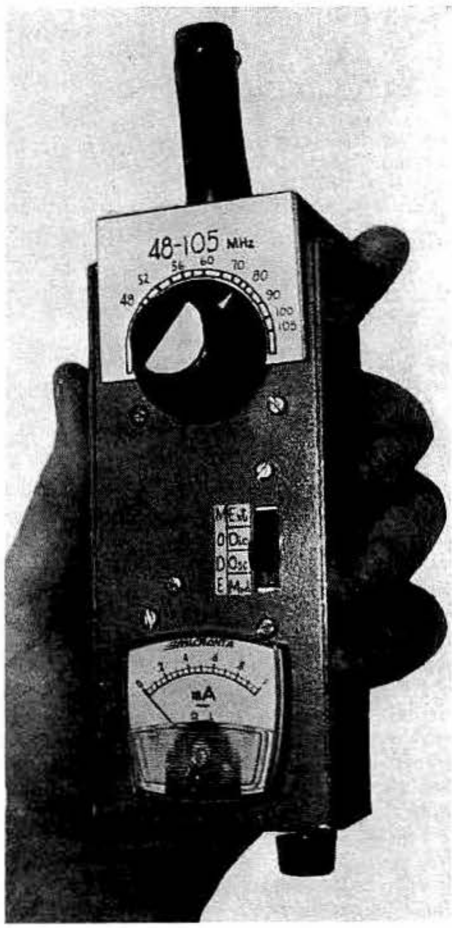
The little gate dipper was checked against a well known commercial tube equivalent and, as near as I could tell, they were just about even. The battery should last for a long time because the current drain is extremely low.

THE GREAT DIPPER

John E. Boyd WA0AYP

Test equipment is essential in the hamshack, as those of us have found when we attempted to get that new piece of homebrew perking for the first time. One of the most useful pieces of test equipment is the grid dip oscillator or simply, the GDO; besides being relatively inexpensive, it is particularly versatile. Need an indicating absorption wave meter? The GDO will do that. How about a modulated signal source? It handles that too. If you are interested in discovering its whole variety of uses, why not purchase one of several books on the subject.

Every item used in this GDO was selected with an eye toward the average home builder. There are no parts which must be specially purchased from the West Indies Export Company or similar outfit. Nearly all the parts, except for the meter, miniature pot, and mode switch, were obtained from the junkbox, or rather, from several junkboxes. If you insist on buying all new parts, total cost of the project will be about $20.



Circuit description

The grid-dip oscillator, in this case more properly termed an emitter-dip oscillator, gets its name from the fact that emitter current in transistor Q_1 decreases when the tuned circuit C_1-L_1 is in resonance with a nearby circuit. This decrease is easily seen by the dip of the meter indicating pointer.

When switched to the diode position, B+ is removed from the oscillator and the incoming rf is rectified by diode D_x; the voltage developed across the 2k resistor is amplified by the meter amplifier and monitored by the 0-1 mA meter. In switching to the signal position, B+ is removed from the meter amplifier but applied to the modulator, and a 1 kHz tone is available from one of the output jacks. In the modulated oscillator position, B+ is reapplied to the oscillator, and the oscillator is modulated by the 1 kHz tone.

Like a patch-work quilt, this GDO was built using circuits from already published articles or books and modified where necessary. The whole circuit is composed of three separate entities–oscillator, meter amplifier, and audio tone generator. The circuit is not particularly critical, but lead lengths and dress in the oscillator must follow good VHF practice, if stable VHF oscillation is to be maintained.

My operating time is spent on the various bands from 28 mHz to 432 mHz. Quite naturally, when I discovered that the GDO would not oscillate satisfactorily over the entire range from 2 mHz to 200 mHz, I juggled values so that it would oscillate well at 216 mHz (for tuning frequency doublers to 432 mHz); then I tried to get as low in frequency as possible. Oscillation was vigorous to about 20 mHz. Coils and scales were then made to cover the respective ranges. It you don't do any homebrewing on the VHF bands perhaps you will find it necessary to

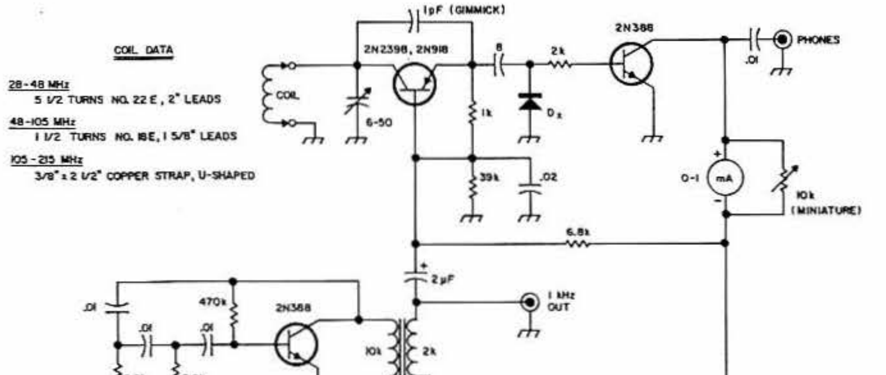
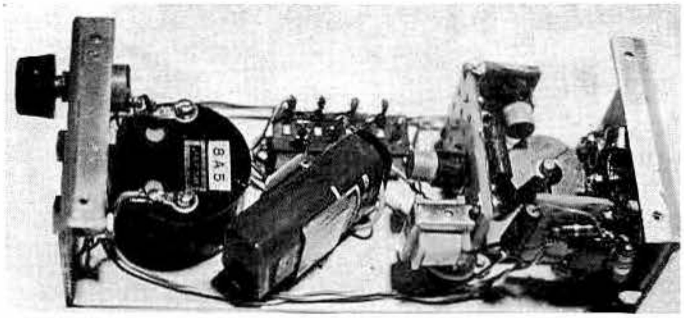


Fig. 1. Circuit diagram of the great dipper. Note that although the 2N2398 is a PNP transistor, the 2N918 is NPN, and if used as the oscillator transistor, problems would arise with voltage polarity. The diode D_x may be almost anything that you have available. The 1 pF gimmick capacitor consists of 1½" of twisted wire.



Internal construction of the great dipper. The modulator and oscillator boards are to the right—the oscillator transistor is mounted right next to the coil jacks.

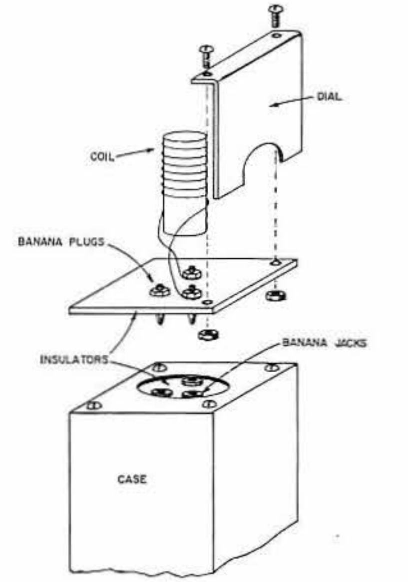


Fig. 3. Construction of the plug-in coil assemblies. The coil forms were made from the plastic containers which hold Polaroid print coater.

change the value of the emitter-collector feedback capacitor, and to juggle the emitter and base resistor values in order to sustain oscillation at your desired frequencies.

Construction

Vector board was used, mainly because I wanted to experiment with component values; however, a printed circuit would be just as good, especially for something such as a club project. It can be seen from the photograph that the meter amplifier and audio oscillator are built on separate boards. This is due to the fact that I built several different amplifiers; the layout would look neater if they were on the same board. Positioning of the rf oscillator and capacitor C_1 as shown in the photograph is recommended, but the placement of other parts is not critical.

Fiberglass board is used as an insulator for mounting the banana jacks and plugs. It cuts and drills easily and appears to work fine. Three banana jacks were used, the third jack being used merely to provide mechanical rigidity. It could also be used, if necessary, to shunt additional capacitance across the emitter and collector on the lower frequencies.

Because a shear and a brake were available, I constructed my own chassis, consisting of two U-shaped pieces of 1/16" aluminum. Using the GDO is a breeze, for it fits the hand very comfortably; if placed on the workbench, it doesn't roll off each time it is bumped. The completed case (1¾" H x 2½" W x 6¾" L) is exceptionally rigid and imparts a reassuringly solid feel when handled. Commercially available miniboxes could be used if you don't have facilities available for rolling your own.

In building the rf oscillator, keep all the rf leads as short as possible; especially the short lead from C_1 to Q_1 and from circuit ground to chassis ground. It was found that false dips could be completely eliminated if a copper strap ¼" wide was added from the capacitor ground lug directly to chassis ground. Apparently the ground on the variable capacitor C_1 is not quite good enough at frequencies above 100 mHz. Various transistors were tried in the oscillator; the PNP type 2N2398 was found to be a good performer, as was the NPN type 2N918. However, the use of the NPN type could lead to problems with battery polarity. Capacitor C_2 is a 1½" length of twisted wire positioned near the collector lead of Q_1. This slightly modified oscillator circuit is from a book describing, among other things, a transistorized GDO which you may wish to use as a reference.

To keep cost low, a 0-1 mA meter was used in conjunction with a simple meter amplifier. If you happen to have a 0-50 μA meter lying in the junkbox, that would work equally well, and the circuit could be simplified accordingly. Several circuits were built for the meter amplifier; the one chosen was a compromise between cost and performance. A germanium transistor was used because it requires less voltage to turn it on. Leakage is low, the pointer of the meter resting just off zero when no coil is in place. Further information can be obtained from January 1966 *73 Magazine*, which was the source for this circuit.

A transistorized audio tone generator is coupled by a 2 μF capacitor to the base of the oscillator transistor for modulation. This modulated oscillator allows the GDO to be used as a versatile signal source. An output jack is included on the panel to allow the 1 kHz tone to be used without turning on the oscillator.

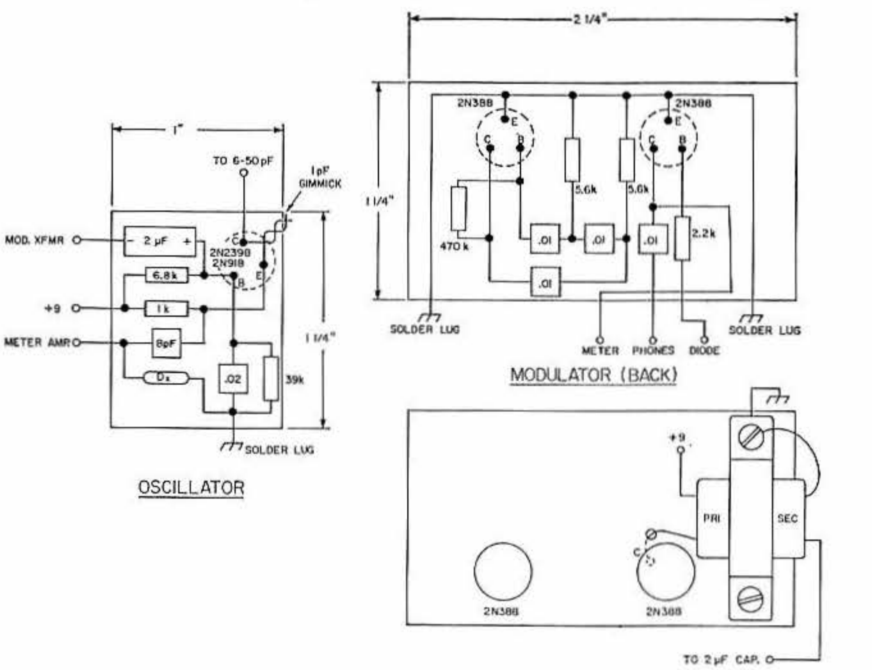


Fig. 2. Layout of the two circuit boards used in the great dipper. Although two boards were used in this case, the circuit could be easily adapted to one board, and even to printed circuitry.

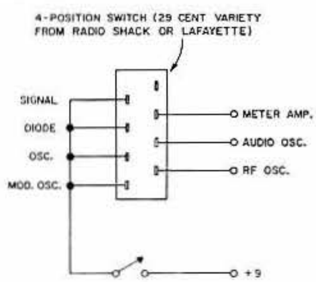
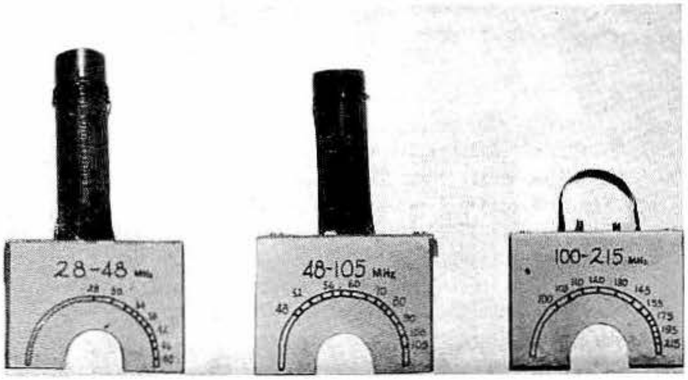


Fig. 4. Wiring the four-position slide switch for the great dipper.



The three plug-in coils for the Great Dipper. Three ranges cover from 28 to 216 MHz. The second harmonic of 216 MHz may be used for tuning up 432 MHz converters and such.

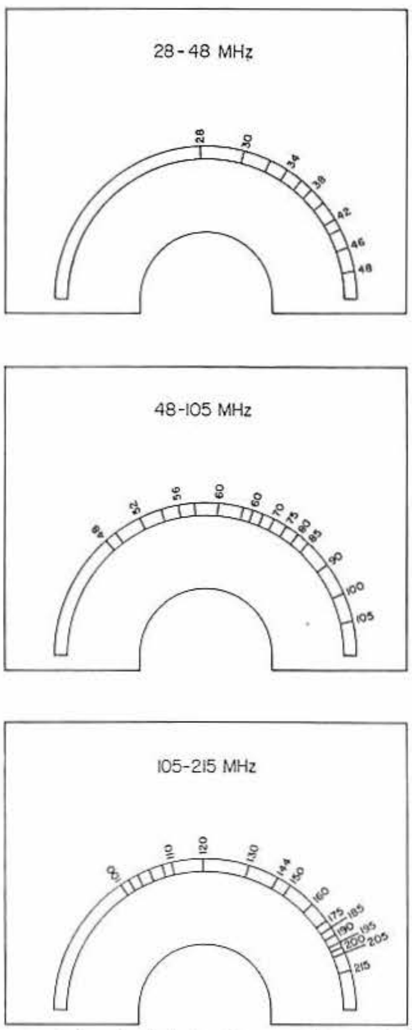


Fig. 5. Full-scale dials for the great dipper. If the construction shown in the photographs is followed closely, the calibration of these dials should be within several percent.

There are a couple of components which not everyone will want to duplicate. One, the sub-miniature 10k pot with SPST switch, was chosen because a very limited amount of space was available; if the unit is built on a larger chassis, the more commonly available *Midgetrol* could be used. The other, a four position switch used to select the desired mode, is a 29c variety available from Lafayette or Radio Shack. It has a peculiar switching arrangement and if you duplicate this project, several hours of experimenting could be eliminated by following the pictorial diagram included in this article. A disadvantage of this particular switch is that the meter does not indicate in the modulated oscillator position.

Using individual scales on each plug-in coil assembly greatly enhances scale legibility, reducing the chance of reading error and speeding frequency identification. This scheme; however, is not original. It was described in a 1957 issue of *Short-wave Magazine*, and is currently being used on a commercial GDO. It requires little additional effort to build the coil assembly in this manner and is, to me, well worth that extra effort. For want of anything else, the coil forms were made from the plastic tubes which contain the film coater supplied with each roll of Polaroid film.

Lastly, ease of tuning is accomplished largely through the use of a 1" skirted knob. Small knobs are simply too difficult to use comfortably.

Calibration and operation

It is best to calibrate this GDO by listening for the oscillator, modulated by the 1 kHz tone, on a general coverage receiver. An alternate method is to use another GDO, placing one in oscillate and the other in diode, tuning for either peak or dip. The scales which were used on this GDO will serve if parts and layout are followed closely.

To use this unit as a dipper, place the mode switch in oscillate, and place the dipper coil next to the coil under test. The turns of both coils should be parallel, and not at right angles to each other. To keep from pulling the oscillator frequency, keep the two coils separated as much as possible, while still maintaining a meter dip. This assures that dial accuracy will be kept high. If a coil is inaccessable, twist a pair of wires together, forming a two turn coil on each end; slip this coupling link over the two coils. Keep in mind that a coil, when it is in a circuit, may not dip at the same frequency as when it is out of this same circuit.

GREATER DIPPER – MODIFICATION

John E. Boyd WAØAYP

Introduction

To the uninitiated, a grid dip oscillator is neither glamorous nor exotic, even if it does happen to be transistorized. But to those who have ever tried to put a coil on frequency, one is worth its weight in microcircuits.

The original model of the *Great Dipper* proved to be a versatile, if unexciting, grid dip oscillator. Intended to be used mostly at VHF, the dipper was limited to frequencies above 28 MHz. To those who seldom operate above 10 meters, the lack of frequency coverage below 28 MHz was a definite handicap. Expanding the frequency coverage downward extends the dipper's usefulness considerably.

Component changes made were not extensive, nor were the physical dimensions of the unit changed. The schematic diagram of the modified circuit is shown in **Fig. 1**, and the pictorial diagram of **Fig. 2** is included to supplement the photographs printed in the original article.

Modification

First, the oscillator circuit board should be rotated 90 degrees from its original position so that transistor substitution or replacement can be made easily. A microwave diode might be substituted for the original glass computer-type diode; this results in better performance at VHF, but its effect cannot be accurately predicted. A 1N21 or 1N23 diode could be used in place of the D4900 called for in the schematic. Best oscillator performance over a wide frequency range results from using a 5 pF capacitor as the collector feedback coupler, but this was a compromise value. If operation is likely to be confined to either the HF or VHF segments of the radio spectrum, some experimentation with this capacitor should result in improved performance over that particular range. For experimentation, use a 3-12 pF or 4-30 pF trimmer.

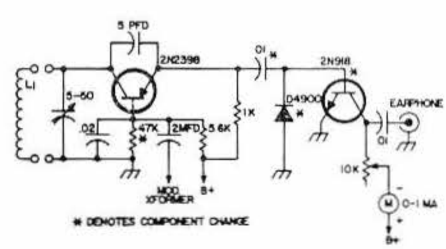


*Fig. 1. Schematic of modified circuit, with component changes indicated by *. L1: 13-23 MHz, 14½ turns No. 20; 22-44 MHz, 5¼ turns No. 24, 45-90 MHz, 1½ turns No. 24; 90-195 MHz, 2½ x 3/8 in.*

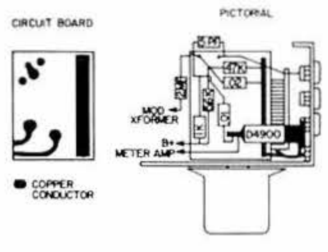


Fig. 2. Pictorial view of the dipper and its circuit board.

To perk up meter amplifier performance, the 2N388 meter amplifier is replaced by a 2N918, a relatively high gain, low leakage transistor.

Although the change was not made in this unit, a 6-100 pF (MAPC-100) variable capacitor could be substituted for the existing 5-50 pF unit. As can be seen from the full-size scales, frequency coverage is narrow on the 13-23 MHz plug-in coil. Those who frequently construct HF gear might benefit from the substitution.

Operation

Operation of the dipper is the same as before, except the frequency range is greater. Another coil must be wound for the 10-25 MHz range, but existing coils were not modified. Calibration is now different from before; full-size scales are included with this article for those who do not have a general-coverage receiver or another grid dip oscillator on hand for calibration.

Oscillation is still vigorous at 13 MHz, which indicates lower frequencies may be reached with a suitable coil plugged in. Similarly, oscillation is still noticeable at 195 MHz, so operation at higher frequencies may be possible.

Finishing Touches

Appearance of the dipper was improved after enlisting the help of a draftsman. The dial and meter scales were professionally inked. **Figure 3** provides full-size copies of these scales.

To improve the legibility of the labels and scales, they were inked on yellow cards rather than on conventional white paper. It's a small point, but for those who use test equipment frequently, the black-on-yellow technique results in less eye strain.

ETCHED CIRCUIT UHF DIPMETER

Bob Corbett W1JJL

I made three models of the dipper. They cover 130-175 MHz, 175-250 MHz, and 250-480 MHz. The first two models use the same size inductor, with the 130-175 MHz model using a larger capacitor for tuning with a ceramic trimmer across it. This trimmer is not shown in the schematic; its value is 7-45 pF and it should be adjusted to cover the proper range.

The 250-480 MHz dipper uses a smaller inductor than the others. It also has a copper jumper (shown in the layout) that the lower frequency dippers don't have.

Each dipper is complete (including the battery) except for the meter. The meters were omitted to save space and money, but can be included if you wish to use a slightly larger case.

Each dipper uses one RCA 2N3478 NPN silicon transistor. These transistors cost only $1.90 apiece, but it's likely that other transistors that are even cheaper could be used. The 2N3478 has odd basing—the only reference is the short case-shield lead—so don't shorten any leads until you're sure that you can keep track of the connections.

The copper side of the board for the dipper is shown in Fig. 2 with the component side in Fig. 3. Use glass or Teflon based board. Paper or bakelite board probably wouldn't be satisfactory. Trim the board to the proper shape with a nibbler. The inductor should be coated with coil dope to keep from shorting it when you use it.

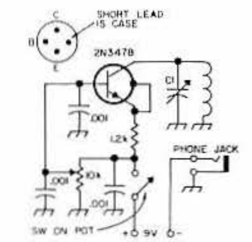


Fig. 1. The etched circuit dipper is very simple. The circuit is almost identical to the one described by WA1CCH in the December 1965 73, but the construction is quite different. C1 is Johnson 160-104 (9 pF) for the two higher frequency dippers, and 160-107 (14 pF) for the 130-180 MHz model. There is a trimmer across C1 in the 130-180 MHz model; see text.

To mount the boards, you'll have to cut a thin slot near the edge of the Minibox used as a case. One way to do it is to drill a number of holes of the proper size in a row, then use a file to finish the slot. You'll have to bend that side of the Minibox out to get the board in. It's held in place by an extra set of nuts on the shafts of the potentiometer and the tuning capacitor. Be sure to trim the leads projecting from the copper side of the board so that they won't touch the metal of the case. The battery is held in place with a simple clip made from scrap metal.

The dipper is very easy to use. But before we get to that, let's check it out and calibrate it.

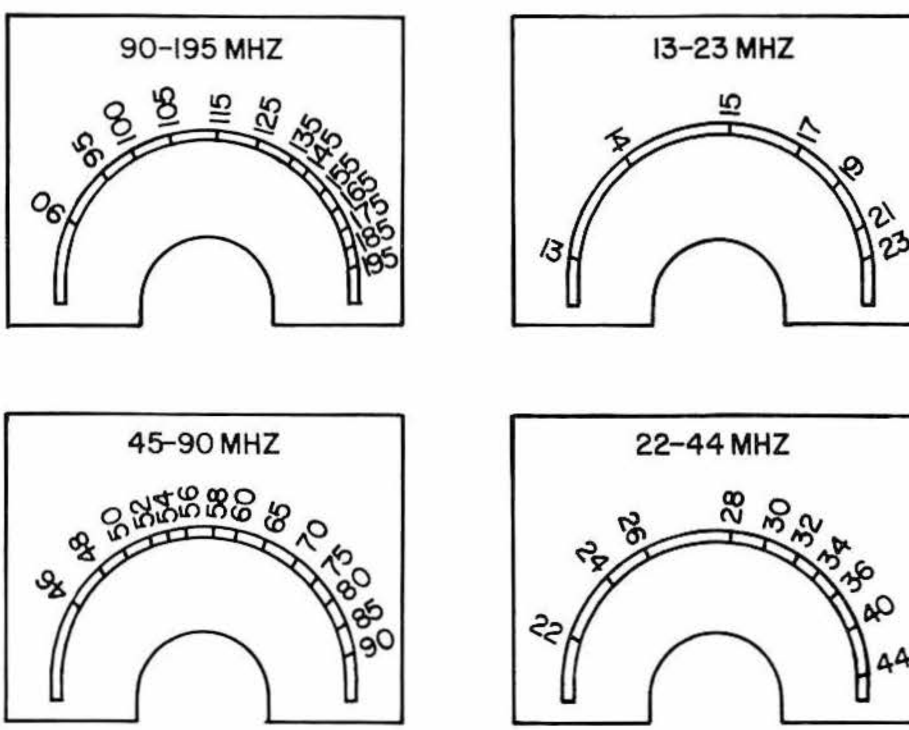
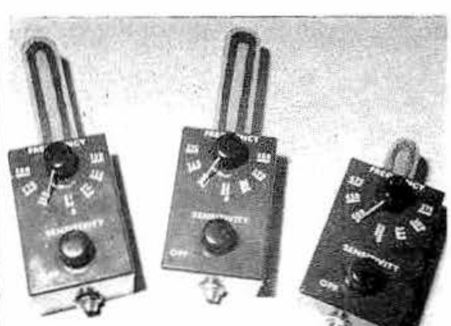
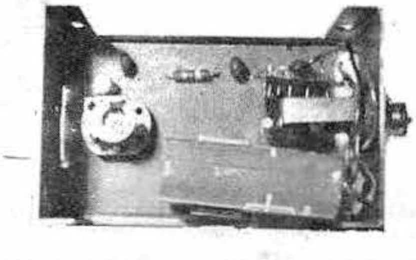


Fig. 3. Dial designs for the various MHz ranges, full size.



The three dippers shown here cover 130-480 MHz.



Here's the inside of one of the dippers.

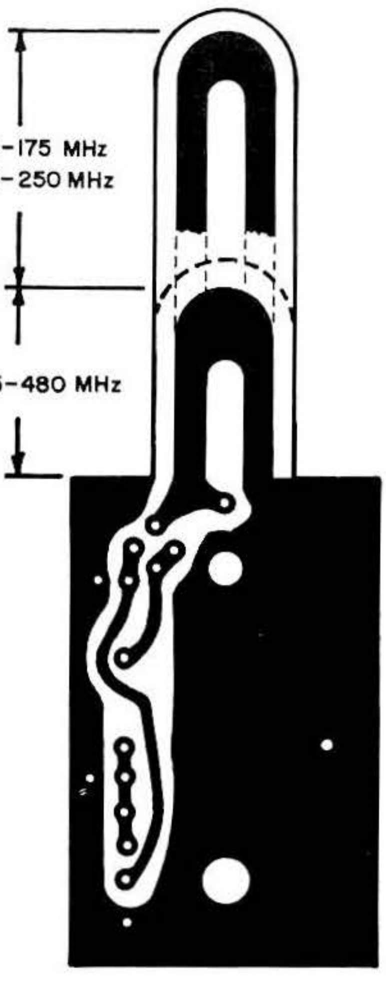


Fig. 2. The copper side of the etched circuit board used in the dipper. This layout is full size. Use board suitable for these frequencies: fiber glass or Teflon.

Plug a 2 to 5 mA meter into the meter jack. You can use a more sensitive meter if you shunt it with a resistor that gives the proper scale. Put the resistor across the meter jack terminals in the dipper if you use the meter for other things.

Turn on the dipper by twisting the potentiometer knob clockwise until it clicks. The meter should show very low current. As you turn the pot, the current should suddenly jump to about 1 mA. That means that the transistor is oscillating. If you touch the coil, the meter reading should drop and the dipper may stop oscillating completely. Now tune the capacitor through its range. There should be a little variation in current, but not too much.

Now you're ready to calibrate the dipper. The easiest method is a sensitive wave meter that covers the range, but it's quite easy to do the job with a TV set. A TV set covers 176 to 216 MHz (channels 7-13) for the low calibration. Then the second harmonics of the dipper tuning 235 to 445 MHz can be received on a UHF TV set (470-890 MHz). If you have a two meter receiver, that gives you another maker at 146 MHz. You can put on the panel markings with Ami-Tron or Datak rub-on lettering.

The dipper should be complete now, and ready for use. Bring the dipper near a resonant circuit in the dipper's range and tune the frequency control. You should get a prominent dip in current when both circuits are tuned to the same frequency. The amount of dip depends on the setting of the pot in the dipper, the distance from the tuned circuit, the Q of the circuit, and the type of coupling.

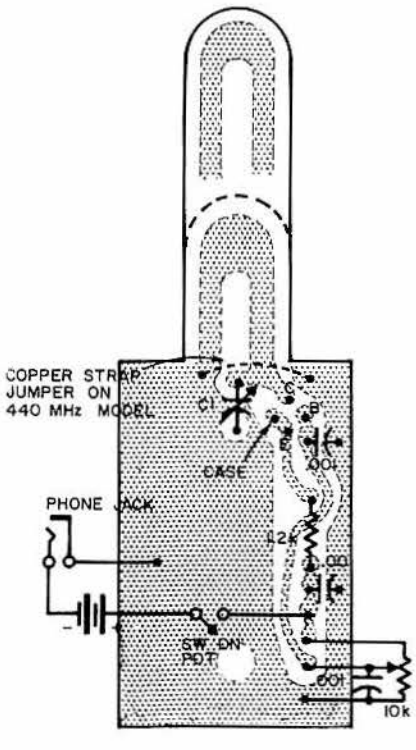


Fig. 3. Component side of the dippers. There is a 7-45 pF ceramic trimmer across C1 in the lowest frequency model. See the text.

In many cases it's easiest to leave the dipper stationary and tune the other circuit.

The dipper can also be used for monitoring AM transmitters by plugging a set of headphones in the meter jack and adjusting the tuning and pot. You can also use the dipper for determining the frequency of another oscillator. Simply tune the oscillating dipper with headphones plugged in until you hear a slight click. You probably won't be able to get a zero beat at these frequencies.

Be careful that you don't use the dipper around an energized transmitter of more than a few watts output or the dipper may be damaged.

These dippers are simple, inexpensive and non-critical to build. After you've build them, you'll wonder how you ever tried to build UHF equipment without a good dipper.

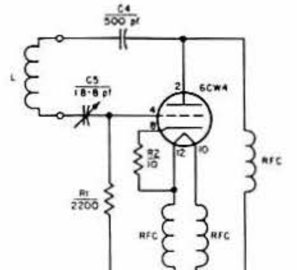
UHF GRID DIPPER

J. Fisk WA6BSO

When building or testing equipment for the 420 mc band, amateurs invariably run into the problem of, "Where am I?". It becomes a little difficult to tell whether you are actually in the band or somewhere nearby. The uninitiated will counter that you should be able to figure close enough, after all the band is 30 mc wide; but even the experienced old timer will confirm that this just isn't so.

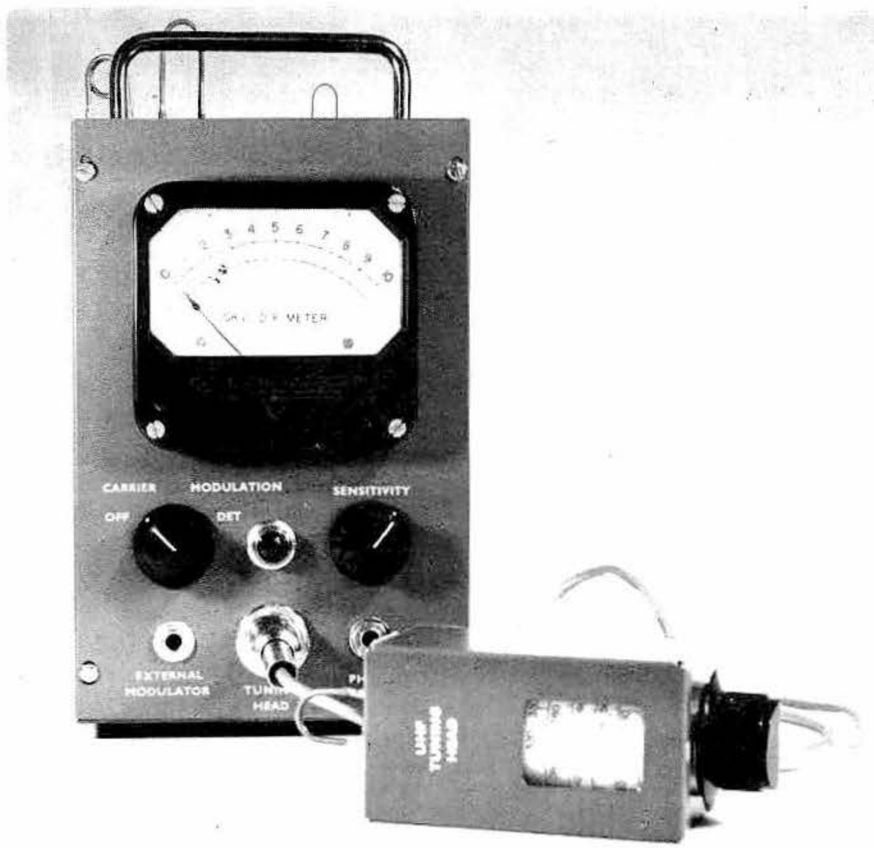
The 420-450 mc amateur band falls between the VHF and UHF television assignments and there is very little to use for a frequency reference point. It is nearly impossible to tell exactly where you are without resorting to expensive commercial gear or lecher wires. Nor is the problem confined to the ¾ meter band; when building crystal controlled converters for 432 or 1296, it's nice to know that the last tripler is really tripling and not doubling or quadrupling. Even with a 45 or 50 mc crystal, it's quite easy to tune up on the wrong harmonic. Remember that a 40 mc change at 400 mc is analogous to a 400 kc change on 75 meters.

There are several commercial instruments that fill this requirement nicely, but the cost of the least expensive of these would buy a pretty respectable all band receiver. Occasionally suitable test equipment appears on the surplus market, but again, the price is prohibitive. The simple UHF grid-dipper described in this article was designed specifically to economically fill this need. It covers the frequencies



C1,C2,C3 STANDOFF BUTTON BYPASS CAPACITORS
C4 BUTTON CAPACITOR (SEE TEXT)
C5 E F JOHNSON TYPE 160-104 VARIABLE
L PLUG-IN COIL
P1 AMPHENOL 91-MC4M MALE CABLE PLUG
RFC's 8-1/2" No 2? ENAMELED WIRE WOUND ON 1/2 W, 100 K COMPOSITION RESISTORS

Fig. 1. Schematic of the rf head of the UHF grid dipper.



from 300 to 680 mc at a total cost that is comparable to a low-frequency kit-type grid-dipper. By using junk-box parts and smart horsetradesmanship this cost may be substantially reduced. I should hasten to point out that substitution of parts in the tuning head should be avoided if accurate dial calibration is desired.

This particular grid-dipper has been duplicated several times and in each case calibration has been within several percent of the original unit; at least as accurate as the familiar kit-type grid-dipper. This is helpful to the ham who does not have access to commercial equipment for calibration purposes. By using the layout and parts described in this article, the precalibrated dial illustrated in **Fig. 8** may be used with a minimum of error.

Although an accessory power supply, modulator and indicator are included in this design, an enterprising ham could use the power supply and meter presently available in any lower frequency tube type grid-dipper. Although using a modified low-frequency dipper is simple and inexpensive, the power/indicator box specifically designed for the UHF tuning head has several features that are not available in inexpensive kit-type units. These include internal 1,000 cycle modulation, provision for external modulation, and voltage regulation which provides the necessary stability at the ultra high frequencies.

The rf tuning head

The heart of this instrument lies in the tuning head itself. There is nothing particularly new or different about the circuit, but at these frequencies stray inductance and capacitance in circuit layout and construction will seriously affect the end result. All the lead lengths must be as short as humanly possible and physical circuit layout must follow standard UHF practice. One of the big problems in building tunable oscillators at UHF is to obtain an oscillator that will tune from one end of the range to the other with no "holes," frequency jumping or instability. The series tuned 6CW4 nuvistor oscillator shown in **Fig. 1** fills these requirements.

Insofar as possible, all the tuning head wiring is done on a point-to-point basis with the components mounted directly to the 6CW4 tube socket or button capacitor lugs as illustrated in **Fig. 3.** To obtain the desired accuracy with the precalibrated dial, this diagram should be followed as closely as possible.

To keep stray circuit inductance to a minimum, all wiring between the coil and tube socket is done with one-quarter inch wide strips of thin copper sheet. In addition, the rotor of the variable capacitor is connected to the 6CW4 grid (pin 4) with a short strip of the same material. The only tricky part of this wiring is the installation of the series capacitor C4. This capacitor is a 500 picofarad button type mounted as shown in **Fig. 5.** The "S" shaped bracket ("A") is made from a one-quarter inch wide copper strip, one and one half inches long and soldered to the mounting stud of the capacitor. Connection to the 6CW4 plate (pin 2) is made with the soldering lug on top of the button.

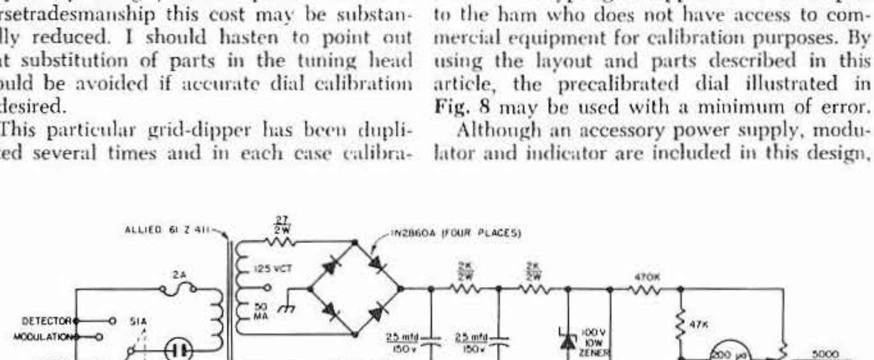


Fig. 2. Power supply and modulator for the UHF grid dipper.

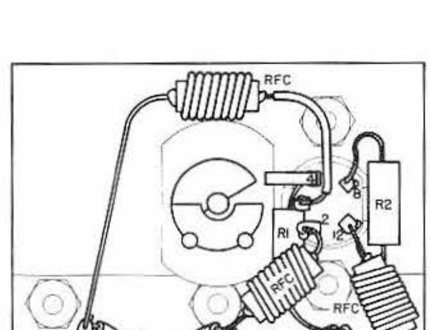


Fig. 3. Critical wiring around the 6CW4 socket.

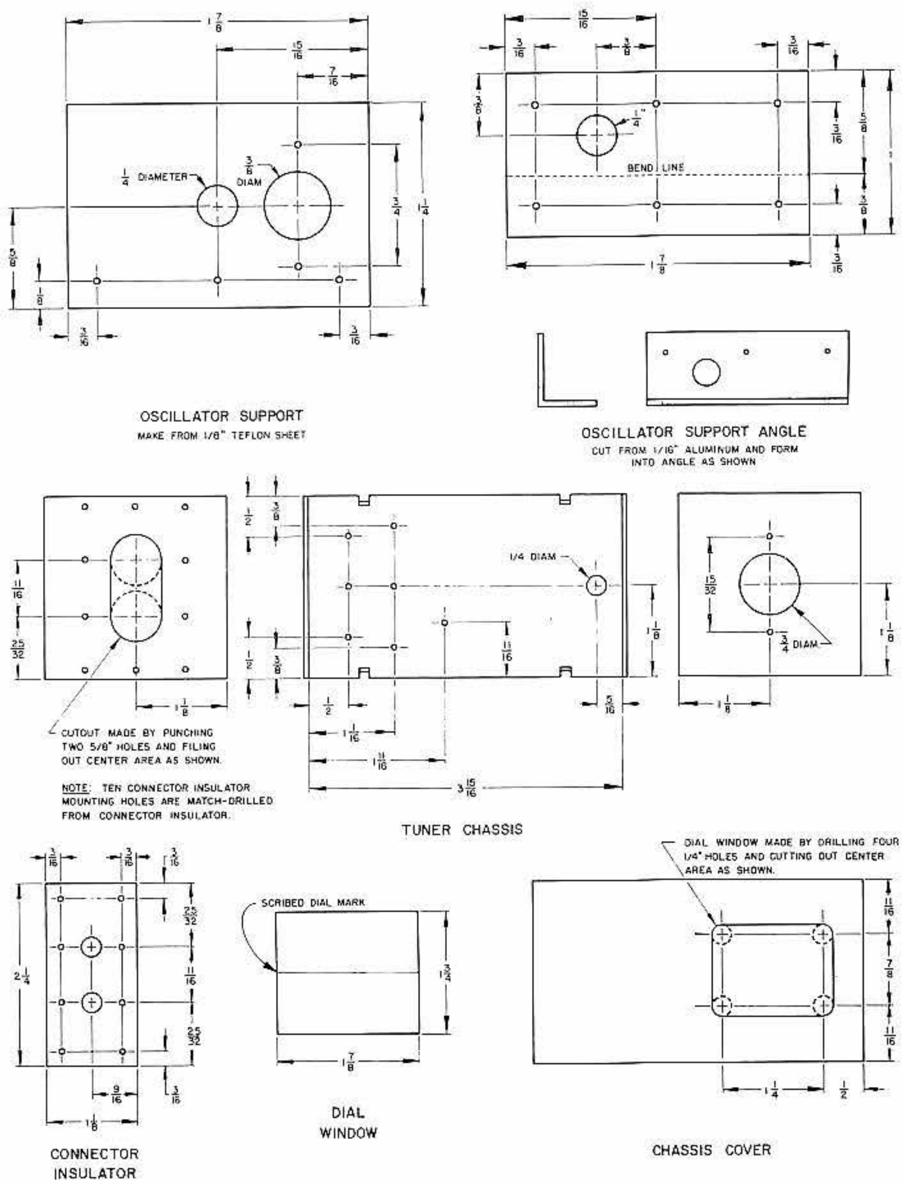


Fig. 4. Layout of the tuner chassis, chassis cover, dial, connector insulator, oscillator support and oscillator support angle.

Connection to the stator of the variable capacitor is accomplished with another short strip of thin copper as shown in **Fig. 5** ("B"). This piece of copper is bent so it touches both stator mounting pins when the unit is assembled; then it is soldered in place.

The oscillator and tuning mechanism are housed in a standard $2\frac{1}{4} \times 2\frac{1}{4} \times 4$ inch chassis box laid out as shown in **Fig. 4**. Although the author's unit is based on an LMB type 107 chassis box, other manufacturers have similarly sized boxes which are equally suitable. The layout of the enclosure is straight-forward and no difficulty should be found in duplicating it. The dial and coil socket cutouts are made by drilling or punching round holes and then cutting out the area between them as shown in the drawing. This is easily done with an Adel "nibbling" tool. All of the small screw holes are drilled with a standard $\frac{1}{8}$ inch drill to pass 4-40 screws; $\frac{5}{32}$ inch holes will be required if 6-32 screws are used.

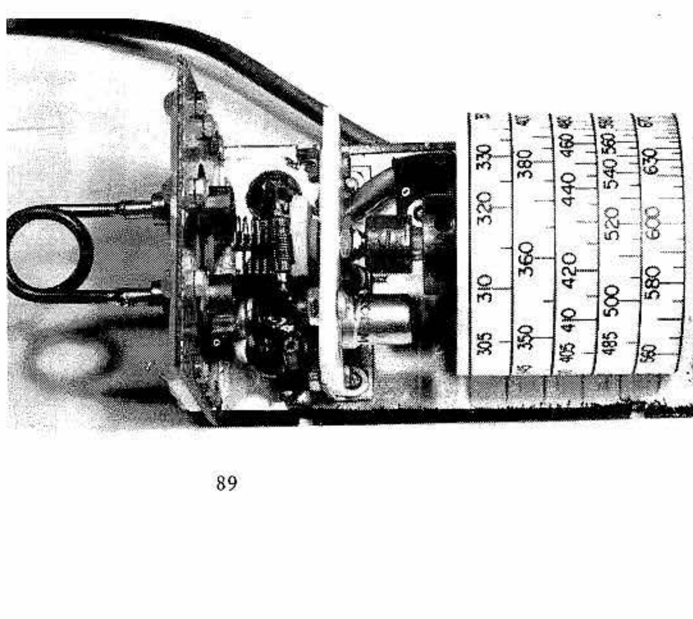
The dial window is cut from a sheet of $\frac{1}{16}$ inch clear plastic to the dimensions shown in **Fig. 4**. A hairline is scribed in the center of this window; if a more distinct line is desired, this scribe mark may be filled in with black india ink. After the tuner enclosure is completed, this dial window is epoxied in place over the dial cutout.

The coil socket is made by installing two banana jacks (E. F. Johnson type 108-740) on $\frac{11}{16}$ inch centers in the Teflon connector insulator illustrated in **Fig. 4** (if Teflon is not available, Polystyrene may be used). This "socket" is installed over the large oblong hole cut in the end of the chassis. The screw holes used for mounting the connector insulator are match-drilled to the holes in the insulator itself. In this way it is properly mated to the enclosure. Although nylon attaching screws were used in the original model, they are not necessary and regular metallic screws will not alter any of the oscillator's characteristics.

To reduce stray capacity to a minimum, the oscillator circuitry is mounted on an insulating sheet. Teflon was used for this purpose in the original unit, but epoxy board with the copper peeled off would be perfectly suitable. Sheet polystyrene is not too desirable in this location because of its susceptibility to heat. The envelope of the 6CW4 gets very hot and the ambient temperature within the confines of the small chassis is quite high.

The general layout of the Teflon oscillator support and associated support angle are also shown in **Fig. 4**. The angle is cut out from a piece of $\frac{1}{16}$ inch aluminum sheet and bent in a vise to form the angle. When these two pieces are mated together, the metal angle will probably interfere with the lower nuvistor socket mounting screw. It must be drilled out using the hole in the oscillator support as a guide. This additional hole is not shown because its exact location will vary from unit to unit and depends upon the accuracy with which the parts are laid out.

The dial mechanism is not complicated, but it is hard to ascertain from the photographs exactly how it is put together. The exploded drawing of **Fig. 6** should help in this respect. The vernier mechanism is an Eddystone 10:1 planetary drive that provides both smooth



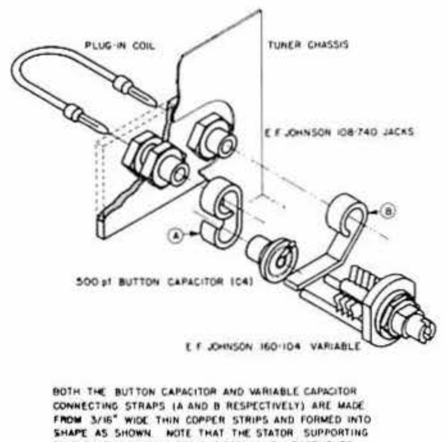


Fig. 5. Exploded view of the connections between the 6CW4 and the coil socket.

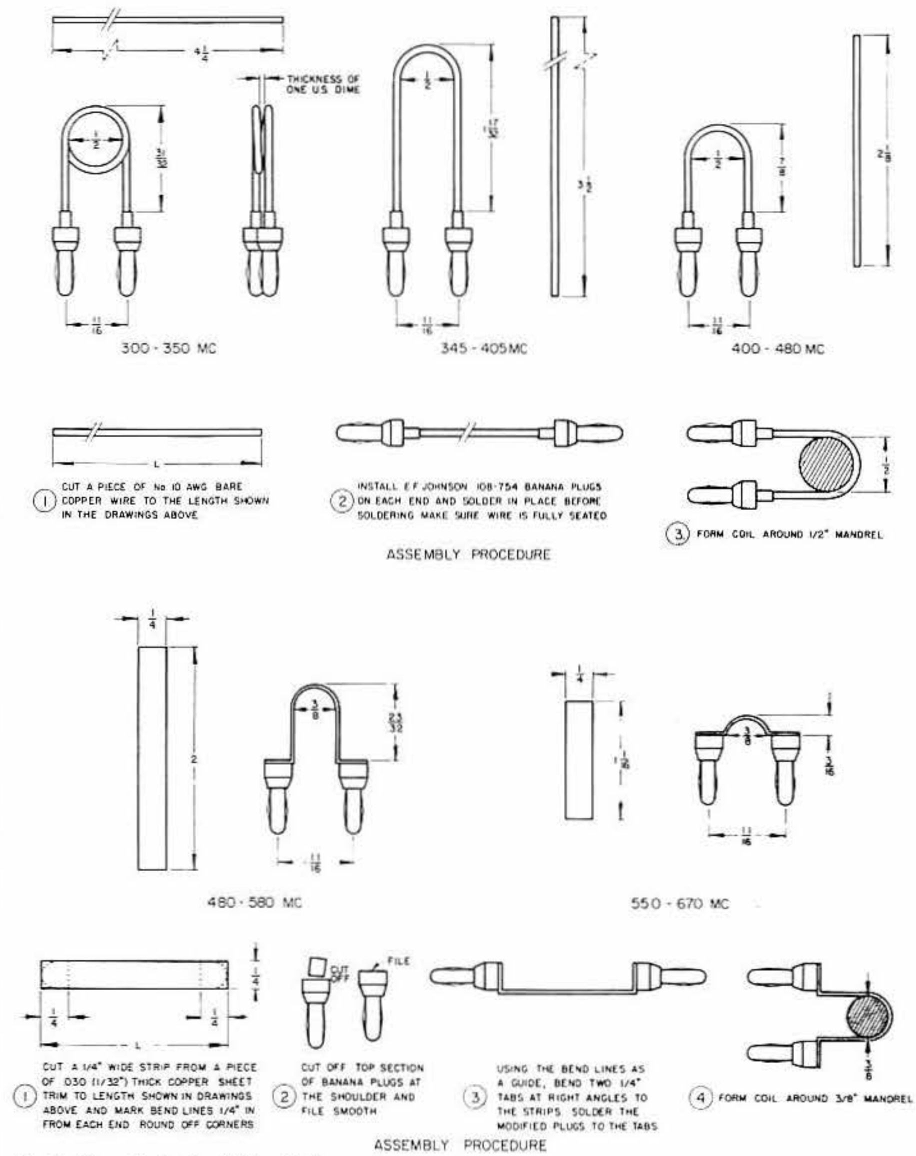


Fig. 7. The coils for the UHF grid dipper.

action and repeatability in a small package. Although this unit is manufactured in England, it is available from many of the larger electronics parts houses in this country.

Substitution of similar drives should be perfectly satisfactory as long as they don't extend more than one inch beyond the front panel of the tuner chasssis.

The vernier drive is connected to the variable capacitor through a ¼ inch polystyrene shaft 1-¼ inches long and the usual "¼ to ¼" shaft couplers. Polystyrene or some other insulator must be used here because the rotor of the capacitor must be isolated from ground. Because of the space limitations inside the enclosure, the coupler at the variable capacitor end of this shaft is only one-half of a standard coupler. A standard "¼ to ¼" coupler is sawed in two and one-half is epoxied to the end of the polystyrene shaft. Save the other half; it will be used for the dial drum hub.

The 8 pf variable capacitor was designed for screwdriver adjustment and its 3/16 inch shaft must be made compatible with the standard coupler. This is accomplished with a bushing made from sheet copper. A short piece of ¼ inch wide, 1/32 inch thick copper strap is formed around the capacitor shaft and takes up the slack between the shaft and the coupler.

The drum dial in the original unit was made from the metal top of a Johnson's Shoe Shine Kit (49¢ at the local grocer's), but any similar closed cylinder 1-15/16 inches in diameter and about 1-11/16 inches long should be suitable; other diameters will void the accuracy of the precalibrated dial. The "skirt" or bottom rim is cut off the metal can at the circumferential notch and a ¼ inch hole is drilled in the center of the top. The remaining half of the ¼ inch shaft coupler that was left over from the polystyrene shaft is then epoxied in place over the hole to provide a dial drum hub. Another hole is drilled in the side of the can 11/16 inches from the top; this provides access to the shaft coupler on the rear end of the vernier drive.

The precalibrated paper dial may now be cemented in place. It's a good idea to cement a piece of white paper the same size as the dial between the dial and the drum, otherwise the label on the can will show through the paper dial. Rubber cement is recommended at this point to prevent excessive wrinkling and distortion of the dial.

When all of the dial parts are completed, they are put together as shown in **Fig. 6**. It's a little crowded in the small box, but all of the parts *will* fit. However, in order to get all of the dial machinery into the box in the right order, a correct assembly sequence must be followed. First the polystyrene shaft and coupler are inserted into the dial drum from the rear. Next insert the Eddystone drive assembly through the hole in the front panel and mate it with the end of the polystyrene shaft. Place the bushing over the capacitor shaft, attach the polystyrene shaft and tighten the coupler; also tighten the coupler at the back end of the Eddystone drive thru the access hole provided in the dial drum. Install the vernier drive mounting screws. Now completely mesh the capacitor plates, center the low edge of the dial in the window and tighten up the dial drum hub. Disassembly must be accomplished in reverse order.

The tuning head is attached to the indicator/power unit through a four-conductor cable three feet long. This cable is attached to the box with a plastic cable clamp mounted in a hole provided immediately adjacent to the oscillator support angle and exits through a rubber grommeted hole at the front end of the enclosure. There is not enough room at the rubber grommet to use a cable clamp, so the cable is epoxied to the box at this point. Before installing the cable, however, check for sufficient clearance between it and the dial drum. It will probably be necessary to route the cable along the corner of the chassis to gain enough clearance.

Power indicator modulator

The power/indicator unit is housed in a standard 9 x 6 x 5 inch utility box (Bud type AU-1040 or equivalent). The layout of this

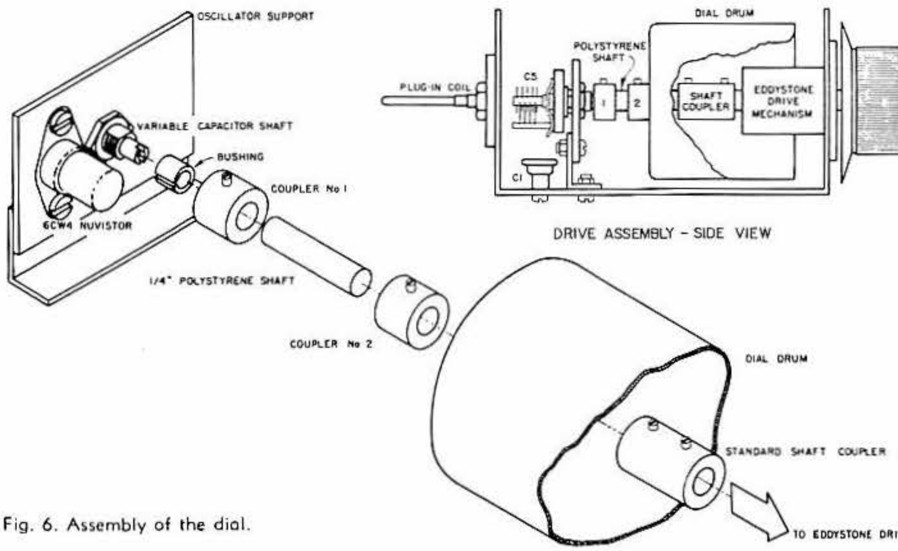


Fig. 6. Assembly of the dial.

circuitry is not at all critical, and just about anything that suits the builder may be used. The only particular caution that must be observed is with the transistorized 1 kc phase shift oscillator. This unit is built on a piece of perforated epoxy board (Vector 32AA18) 1-3⁄16 inches wide and 1-11⁄16 inches long. To preclude any 60 cycle pickup, this board is situated on the opposite side of the chassis from the power transformer.

In the author's case all the power/indicator components were mounted on a 4 x 5 x 1 inch aluminum chassis. This chassis was then mounted to the front panel of the utility box with the phone jack and power plug mounting nuts. Two large diameter holes (1-⅜ inch) are punched in the rear panel to provide access to the fuse holder and to pass the AC power plug. A chassis handle (Bud H-9168) on the top and rubber feet on the bottom just about complete the unit. There is one other addition however; five pairs of 5⁄32 inch holes, drilled on 11⁄16 inch centers along the rear edge of the top of the box provide convenient storage for the five frequency determining coils. A coat of spray paint and some Datak "Letraset" dry transfer labels are the finishing touches.

Calibration and operation

Without access to existing 420 mc equipment with known frequency characteristics, exact calibration in this band is impossible. However, this grid-dipper may be checked on the other ranges with the aid of an all-band television receiver. If the circuit layout and construction techniques described are closely followed, good correlation can be obtained and reasonable accuracy insured. The bands that are likely to be the furthest off are the lowest and the highest. In the lowest the coil spacing is quite critical and in the highest a slight change in length will move the frequency several megacycles. An accuracy of 2% at 600 mc is plus or minus 12 mc; close attention to the specified dimensions should provide accuracy better than this.

Operation of this grid-dipper is exactly the same as any lower frequency unit. It may be used in determining circuit resonance, detecting parasitic oscillations or as a signal generator. Because of its extended range, it has been found to be very useful in determining the series resonance point of rf chokes and ceramic bypass capacitors.

In the detect mode, this unit will indicate rf voltages as low as 50,000 microvolts. More sensitive operation may be obtained if it is used as an oscillating detector. In this case headphones are used and an audio beat note will be heard when the grid-dipper is tuned to the oscillator being checked. In the upper frequency ranges, it is usually difficult to obtain an actual beat note, and only a "tick" will be discernible when you tune by the frequency of the unknown energy.

When the oscillator is tuned between 605 and 650 mc, there is sufficient second harmonic energy to provide a strong reference signal in the 1215 mc amateur band. This is particularly useful in the initial tune-up of converters for this band. Use of the internal 1000 cycle modulation aids in distinguishing the grid-dipper signal from other rf sources that are present throughout the spectrum.

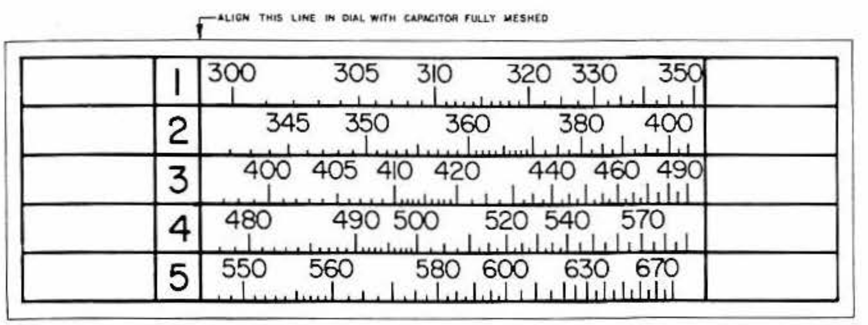


Fig. 8. Full size dial scale.

WIDE RANGE VHF-UHF DIPPER

Bill Hoisington K1CLL

Most dippers for amateurs that I have seen so far, not counting the $400 ones, stop around 200 MHz just as you are about to enter the fascinating UHF region. We do have the 432 and 1296 bands, so let's become more familiar with them.

After all these years of "grid-dipping" we find ourselves without a grid, so it just becomes a "dipper". To retain the prestige of a hyphenated name we can call it a "dipper-generator". Most grid-dippers have been used as generators, but this one has built-in modulation, variable input-output coupling, controlled Q, and several other interesting features. Best of all, it goes all the way up to 1296 MHz.

When this little unit is completed it may be used as a dipper for determining the resonant frequency of VHF and UHF circuits, as an indicating frequency meter with an adjustable Q-multiplier, a field strength meter and modulation monitor, a sensitive regenerative receiver, or a CW and MCW signal generator. You can also use it as a harmonic monitor or as a frequency transfer unit from one transmitter to another.

Several circuits must be considered when building a wide band instrument such as this. For example, you should change circuits around 100 MHz and again at 600 MHz, give or take a few hundred. Below 100 MHz coils are good; from there to 600 MHz you can use ¼ wave resonators, and after that the ½ wave job becomes rapidly the best method, up to 1300 MHz.

Plug-in rf heads

I have made no attempt to cover the complete range from 130 to 1300 MHz with one oscillator. By using plug-in tuners you may vary the components to suit the frequency. On 50 MHz for example, you may use a low cost transistor, a coil, and a 25 or 50 pF capacitor. From 100 to 600 MHz you use a better transistor, a ¼ wave strap, and a 10 or 15 pF capacitor. In the microwave region up to 1296 MHz you use the best transistor you've got, ½ wave lines,

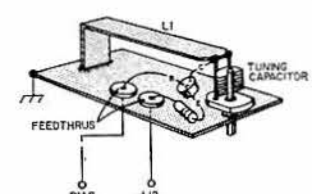


Fig. 1. Basic VHF/UHF oscillator circuit.

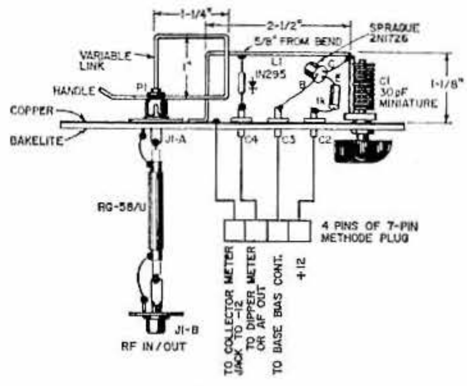


Fig. 2. 130 to 300 MHz tuning head.

and a small butterfly capacitor of 3 to 5 pF.

If you break the circuit at the right point, it simplifies things—then the two halves may be connected through a miniature 7-pin socket and plug as shown in Fig. 2. All four leads are reasonably dead to rf. You can leave out some of the audio if you like, but it's very handy to have a modulated signal. If you're running triple or quadruple conversion, it's nice to know by it's modulation which is the signal and which might be a *birdie*. As far as dials are concerned—it makes calibration and reading a lot easier to have only one band or range per dial.

130 to 300 MHz oscillator

Fig. 1 shows the basic ¼ wave circuit; Fig. 2 the complete rf unit with control, af output and modulation.

The circuit itself is very simplified, as seen in Fig. 1; there being only one inductance, L1, and no choke coils. This should make for a flat tuning oscillator without power dips as it is tuned over a 2 to 1 range in frequency, and it does just that. With a 2N1726 in the circuit there is a smooth power output curve from about one volt rf at 130 MHz down to ½ volt at 300 MHz.

The rf coupling jack J1 couples the rf energy both in and out. This is because L1 acts as either a detector resonator or an oscillator resonator, as required. Actually this rf jack can be used as shown in

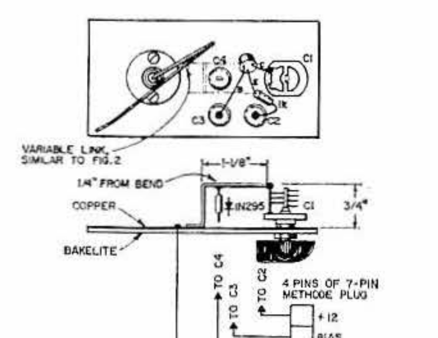


Fig. 3. 300 to 600 MHz oscillator with variable link.

Fig. 2. P1 is a variable link to L1 and is plugged into J1; J1A has a few inches of cable between the white ABS plastic front panel and the copper clad bakelite sub-panel. Because the phono plug is rotatable, a nice variation in rf coupling can be obtained. The coax cable and J1B get the rf out to the front panel for easy use with antennas, probes, cables, etc.

The emitter goes to a 1K resistor then through a coaxial bypass capacitor which gets the dc in and out and leaves the rf behind. These feed-through type bypasses are very necessary—do *not* skimp on this item.

300 to 600 MHz unit

Fig. 3 shows that this unit is essentially the same as the last, except for dimensions. I used a 2N1141 here although many others will work too. It tunes smoothly from 300 to 600 MHz; use the variable link feature as in Fig. 2.

900 to 1100 MHz

For this frequency range we need a little different approach. From Fig. 4 we can see that we now have two ¼ wave lines on which low-voltage points can be found to attach the base and collector resistors. Most of the ¼ wave portion of the lines on the transistor end are actually inside the case. The places where the base resistor and the 500 ohm collector resistor are attached to the ¼ wave lines can be found, or checked, by watching the rf meter and touching the lines with a pencil. At the proper point no change occurs in the rf output; sometimes it even increases.

The diode circuit of Fig. 6 is not ideal but it works. I have several of these around the shack and they work very well for detecting 1296 Mhz energy. Even ordinary hook-up wire will support the assembly of Fig. 6 about ¼ inch below the rf lines; you will soon find the best spot with the unit oscillating. The rf input jack and associated loop L3 are fastened so that L3 is in place over L1 and L2, and it's coupling can be varied in a semi-fixed fashion.

At this point we should mention that as a "dipper" the circuit is still working fine; also as a signal generator. It also serves as an rf detector but as the frequency gets up into the microwave ranges it is not quite as good as the tuned rf detectors featured in another article in 73 Magazine. Ideally, you should use the dipper on microwaves as a modulated generator and couple

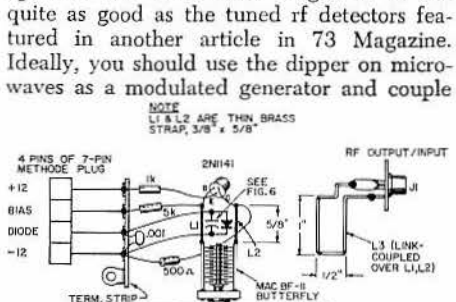


Fig. 4. 900 to 1120 MHz oscillator circuit.

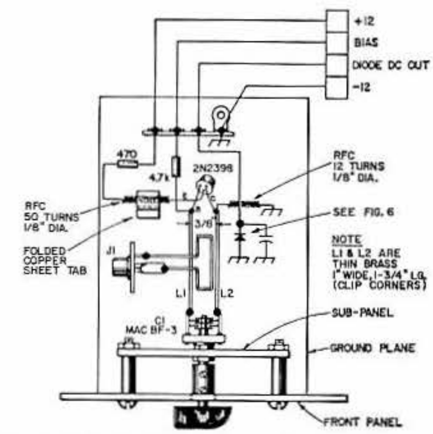


Fig. 5. 1200 to 1300 MHz oscillator and layout.

it into the unknown circuit; then a probe attached to *another* tuned detector should be coupled into the unknown circuit. There are quite a few variations using the dipper as an oscillator that you will find useful if you use a little ingenuity.

In the microwave detector line, my experience indicates that the plunger tuned coax cavity line is the best, the tuned trough line next, and the circuit of Fig. 5 next best. As a dipper, generator and regenerative receiver it is still good at 1296 MHz. Just to check, I plugged an antenna into J1, put an audio amplifier across the diode and copied a small transistor oscillator across the room. The base bias control works as a very smooth regeneration control. Smooth regeneration, as we will see later, is very important for maximum sensitivity when looking for harmonics and weak signals.

1200 to 1300 MHz unit

Fig. 5 shows the 1296 unit; I have used this circuit for many months as a dipper, variable-frequency generator, modulated-oscillator source, and as a regenerative receiver for 1296. In this circuit I used a negative dc grounded collector return. Don't short the base plate to the modulator base. Note that one end of the diode is tied to the base plate; this lead is brought out as the minus 12 volt lead. You can also use it ungrounded as in Fig. 4—you can use a 5th lead in the 7-pin plug and keep the diode isolated from the minus 12 volts. Suit yourself, just remember that *all* units have to use the same leads, as they all plug into the single modulator rf unit.

I just plugged a little 12 element Yagi antenna into this dipper and it works nice and smooth as a regenerative receiver. Please note, this is only for test purposes around the shack. You can hear with it, but not *that* good!

I had to put a choke in the cathode lead on this one, and tune it (the choke) with a piece of copper foil. A choke was needed in the collector lead too; after all this is the L-band microwave region.

The rf input jack J1 is mounted on a bakelite upright. Be careful of vertical metal

pieces attached to the base plate; they only need to be two inches long or so to become Marconi antennas on 1296! Bring the base resistor and the collector choke away from the lines in a perpendicular fashion—it helps.

The total length of the diode and it's two leads, from ground to the tiny .001 capacitor C2 is about 1½ inches; it is spaced about 3/16 from the ground plane. The bottom edges of the lines are about ½ inch from the ground plane.

The transistor presently in the unit is a selected 2N2398; about half of the dozen or so I have here go to 1300 MHz, a couple go to 1400, and the rest to 1100 or 1200.

Don't be alarmed that L1 and L2 are longer than those of Fig. 5, the smaller butterfly capacitor does that. You can make a choice as to capacity, length of brass, and desired rf range. You can use a 5 or 10 pF capacitor for C1, shorter lines, and tune over 1300 MHz. In fact, I have reached 1600 MHz with this circuit!

Modulation and control

Fig. 7 shows the circuitry for bias control, modulation and audio. Don't let it scare you. It's just the same old deal of doing what has to be done for control purposes, and from then on just turning the knobs to get what you want.

I have found that a very good plug and jack can be made by using an ordinary 7 pin socket and a Methode 7 pin bakelite plug. Unfortunately, I have never found a miniature tube with a bakelite base; they are always made of glass, so you will probably have to buy the 7 pin plug.

The minus 12 volt lead goes to the collector meter jack and then to the minus 12 volt of the power supply. This puts the rf panel ground at minus 12 volts and the audio af panel at plus 12. Of course, you don't have to ground the plus 12 on the audio panel, I just have that habit.

The base return goes through a 5K resistor and then to the bias control potentiometer. The diode dc/af output goes to af jack J2 and the meter M1 through the meter sensitivity control. This potentiometer is selected to suit the meter; I have used a 10 K unit with a 500 microampere meter. Note that part of this resistor should be used when af output is desired, otherwise the meter shorts out the af.

Audio modulation

You might think that just about everyone knows how to build an audio oscillator. Mine did oscillate, but the tone! And the wave-shapes, hoo-boy! I used an af transformer with the collector on one side and

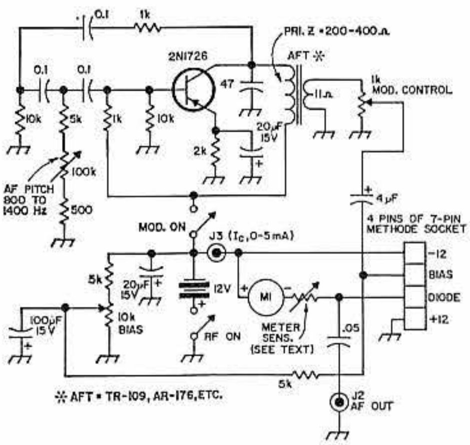


Fig. 7. Power control, modulation and audio circuitry. This circuit is used with all the rf heads.

the base on the other. So, once again to the handbooks and once again practically zilch. I did get the idea for a phase shift oscillator out of one of them, even if the circuit didn't work at first. After considerable experimentation I can recommend the circuit shown in Fig. 7. It works! In addition, the modulation may be adjusted to exactly 1000 MHz. This is very useful as many microwave test amplifiers have built-in narrow band af audio filters centered on 1 KHz. There is also a modulation gain control. This helps if a nice tone is desired.

Almost any small transistor output transformer will do the job for the af transformer, but don't go over 400 ohms impedance in the collector winding. Note the 1K resistor between the collector and the phase shift network; this reduces feedback to the base and may have to be increased or decreased depending on the gain of your transistor at 1000 Hertz.

I usually run the rf current (collector dc) between one and two mils with the 2N1726 transistors; other transistors may take more. A number 48 bulb in the collector lead may save you a $3 transistor. With the 2N1141 the rf output keeps climbing up to 4 or 5 mA collector current. You will readily find the best place to operate. When the collector mils keep climbing and the rf output starts to drop off, back off!

Operation

Dipper

As a general rule "dipping" is easier in the VHF region and gets more difficult as you go into the microwave region. On HF you couple one coil end on to the other; on VHF you bring it near, and on UHF you have to work to get the necessary coupling or use a probe.

With nothing near the dipper, swing the dial through the range to make sure it has no dips of it's own. The VHF/UHF units without chokes described here do not generally have such dips. Unwanted dips can be caused by chokes, resonant feed wire lengths, metal supports, and rf links and cables among other things.

When you do get a dip after coupling to the unknown circuit be sure and change the resonance of that circuit for a final check while watching the dipper meter. If the test circuit is a tuned circuit vary the tuning and see if the dipper will follow it—it *should*. If all else fails, use the dipper as a generator. Since it is very difficult to get the far end of a cable matched exactly over much of a frequency range, *expect* to find external dips in the dipper when using a cable.

Indicating frequency meter

Always keep the transistor plugged in and the base bias at zero so the diode is doing the work. When you advance the bias, collector capacity will cause the dipper frequency to change a little—more with some transistors than others.

For finding a weak signal you can use regeneration by turning up the base bias, but watch out for slight frequency changes. This regeneration can be very handy for finding weak oscillators or hard-to-find rf energy. Use the rf input loop with care; the least coupling is the best. Remember that some cables and terminations will detune L1.

Field strength meter and modulation monitor

The first part is obvious; use a small antenna or probe, get some signal in, and go ahead. Do not use any base bias to start with. If you are working with a very weak signal you might have to push the bias up for regeneration.

The modulation monitor is simply our often-described system of diode detector, transistor amplifier, and padded ear-phones. You can actually hear what your own transmitter sounds like to others. I use it on every new rig and after every circuit change. You don't need much of an antenna or probe when listening to your own rig; don't overload the diode when checking modulation. In fact, use light rf coupling and plenty of audio gain to hear yourself as others hear you.

Regenerative Receiver

Plug an audio amplifier into J2, Fig. 7, advance the bias control, and tune. I have heard several UHF TV stations from Massachusetts up here in Peterborough, so it is really sensitive. One nice feature of this circuit is that the regeneration turns into oscillation very smoothly. Stability is good too. You can heterodyne a crystal controlled two meter signal and copy CW with it. Not bad for a 144 MHz blooper!

To transfer signals from one transmitter (A) to another (B), just tune in A, then shut it off; listen for B and tune it in. That's all. Harmonic monitoring is easy: just tune over the suspected range in the regenerative condition. It is particularly good because only *one* frequency is present in the receiver. This is *not* the case when using a super-het receiver for monitoring harmonics.

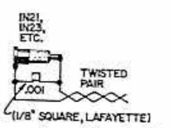


Fig. 6. RF detection loop for half-wave oscillators.

Signal generator

One of the big features of this circuit is the presence of an rf meter right in the proper place circuit-wise. The modulation also helps, especially when running triple or quadruple conversion in a receiver. The modulation control is very convenient, at full on its spreads the signal across 20 or 30 kHz on a selective receiver. For checking a difficult to get at circuit, use a cable and probe, either capacitive or inductive, to get the signal into the unknown circuit.

I often use one of these units for antenna and receiver tests. I just plug a little two element beam into the rf jack and set it out away from the shack; often one or two hundred yards away. There is nothing like tuning up pre-amps with your antenna system connected. For antenna tests it is used in reverse.

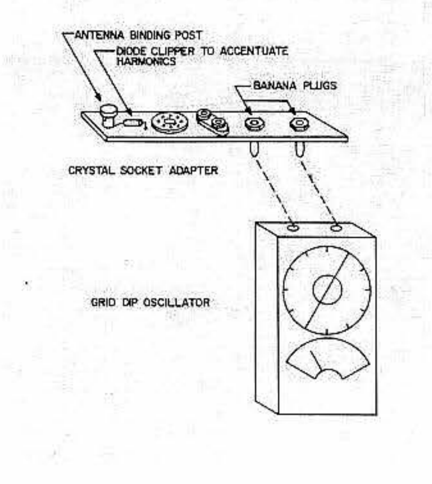
EXTRA SERVICES FROM YOUR GRID-DIP OSCILLATOR

W. B. Cameron WA4UZM

One of the handiest instruments around the average ham shack is the grid dip oscillator, but many hams do not get all of the advantages this little instrument can offer. Most people know that it is useful for finding the resonant frequency of an LC circuit, or for generating a signal someplace in the range, although it is not quite a substitute for a well calibrated signal generator in this respect.

Many people do not realize that the grid dip oscillator makes an excellent crystal calibrator as well. The typical grid dip oscillator uses a two-terminal coil and a two-section variable capacitor, connected in the form of a Colpitts oscillator circuit, with the variable capacitor providing the voltage division for proper feedback. This same circuit, with a quartz crystal replacing the coil, becomes a very satisfactory crystal oscillator. In this case, the variable capacitor becomes a trimming capacitor capable of putting the crystal on the proper frequency with considerable accuracy and also allowing a fairly wide latitude higher or lower for checking bandpass.

The meter reading gives an index of crystal activity. What is required is an adapter to match the pins of the crystal holders to the coil socket of the grid dip oscillator. I have made up such an adapter for my particular unit which consists of a 1½ inch by 4½ inch piece of masonite which carries two banana plugs to insert into the oscillator socket, and several different sizes of crystal holders, all connected in parallel, to accommodate any crystals I happen to have around the shack. I carry in my tool kit various assorted crystals. These give me spot frequencies for band edges and other reference points on all of the amateur bands.



Crystal socket adapter for grid dip oscillator extends the unit's capability by enabling it to read crystal activity.

In checking the higher frequency bands, I find it useful to add a diode clipper and have one permanently wired on the same adapter board. This is a 1N69 which simply goes from one side of the crystal to a terminal point at which I can attach an antenna or a lead to the input jack of the receiver. By simply attaching a short length of wire approximating a quarter wavelength at this frequency, I can provide a strong enough signal from the shack to enable me to check out my direction finding loop in the automobile fifty feet away.

In tuning up my 2 meter FM gear, I plug in a 3061.25 crystal (which is the transmitter oscillator crystal for my Link 2m FM unit) and then couple from the 1N69 to the input of the receiver. This provides a signal stronger than most of the local signals on the band, and adequate for initial tune-up. For finer adjustment of the i-f strip, I clip the lead from the 1N69 to the chassis close to the antenna input jack and the leakage provides a signal of the order of .2 μV, which is useful for final adjustment of the critical tuned circuits, the squelch control, and others. For best results, I leave the oscillator and the receiver on for a half hour or so to warm up, and then with the variable capacitor in the grid dip oscillator, I zero-beat the incoming signal of a station generally considered to be on frequency. Once this is done, I have a signal source on the bench with which to check the receiver for passband balance as indicated on the microammeter connected to the discriminator output.

GDO TO FIND C

F. C. Rayer G3OGR

Most amateurs have a grid dip oscillator lying around, and an easy accessory can allow it to be used to read the values of unknown capacitances up to about 1000 pF. This is useful for unmarked surplus, those with obliterated markings, or to find the swing of small variables. Or we may check the best value found in some circuit position with a preset or variable, then measure this and substitute a near value fixed capacitor.

Figure 1 is the circuit. C1 and C2 are on the lid of an insulated box, carrying also spring terminals for CX. The capacitors have good knobs with pointers. Coil L can be half a dozen turns of stout wire, self-supporting, or anything which comes within a convenient range of the GDO (say 2.5–10 MHz) with both variables fully closed.

To calibrate, close C1 and C2 fully. Tune the GDO for the usual dip. Note the frequency on the box for future use. Take a few 1% capacitors, such as 100 pF, 200 pF, and so on, up to a total of about 1000 pF. Clip one to CX. Open C2 to restore the dip on the GDO. Mark the capacitor value on C2 dial. Series and parallel capacitors give more values. For example, 100 pF plus 200 pF in parallel gives 300 pF, while 500 plus 200 gives 700 pF, and so on.

Restore C2 to its fully closed mark. Repeat to calibrate C1, this time using

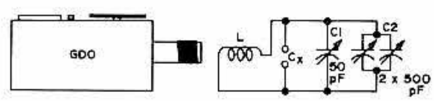


Fig. 1. GDO to find C.

capacitors such as 5 pF, etc., up to about 50 pF. When you see how the scales mark, estimate intermediate markings, to fill in.

Once calibration is finished, it is easy to find a capacitance value from about 2.5 to 1000 pF. Close C1 and C2. Put the GDO near L and tune the GDO for dip. Clip the unknown capacitor across CX. Open C1 or C2, as appropriate, to restore the dip. Read off the value from the scale. That's all there is to it!

GDO COIL EXTENSION

Bill Turner WA∅ABI

A grid dipper is a great piece of test equipment and belongs wherever rf equipment is to be designed, constructed, or serviced. All writings on the subject seem to be prefaced with this comment, and I hesitate to break tradition. Now that the formalities are over, we will proceed with the subject matter.

Probably the one most inconvenient feature of all grid dip meters is the physical size of the instrument. This holds true for the two unit commercial models as well as the more common self-contained types. It is not

so much that they are large but rather that the head will not always fit into the nooks and crannies which seem to be designed into most equipment. This situation will more than likely become more severe as integrated circuits come into more general use. At lower frequencies the coil assembly is usually long enough to reach to within shouting distance of the desired circuit, but as the frequency is increased the dipper coil shrinks to perhaps an inch protruding from the case. Try getting this even near a circuit buried 2 or 3 in. deep in a chassis and you will fully appreciate the magnitude of the problem.

There is a way of relieving the difficulty which requires neither a great deal of time nor expense. It is only necessary to put to use some basic theory which each of us was required to know in order to get a ham license. Required are perhaps a 3 ft length of small coax (RG 174/U), 6 in. of hookup wire and a ballpoint pen casing. The innards of the pen are removed, and the business end reamed slightly to accept the ends of a ½ in. diameter one turn link formed of hookup wire. Inside the barrel of the pen the ends are soldered to the coax, insulated, and cemented in place. The remaining wire is formed into a 2 turn link which fits snugly on the coil form of your grid dipper. This link is soldered to the opposite end of the coax and secured. Shrinkable tubing is perfect to cover the joint.

The next time you face this perplexing problem hold your head high and fear not. Merely slip the link over the coil form, place your probe so as to allow coupling into the desired circuit and proceed as usual. The only difference will be a more or less fixed load on the oscillator which doesn't affect its ability to indicate resonance. As always, best results are obtained with minimum coupling.

Chapter VIII

Noise Generators

SIMPLE NOISE GENERATOR

George Rubis K9ONT

As anyone knows that has done any work at all on receivers, whether it is a conversion or simply substituting a "hotter" tube in the front end, we get to the point where we begin to wonder if the adaptation was worth while or have we been fooling ourselves.

A noise generator using one of the noise diodes (IN21 or IN23) can give an indication if any improvement has been made.

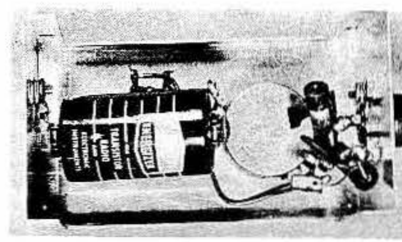
The circuit is straight forward, but with one addition that others that I have seen do not have. The voltage is regulated by a Zener diode.

The reason is obvious to anyone who has worked with the simpler type of noise generator. The results are not always consistent from measurement to measurement and from day to day. The voltage and current vary with the setting of the variable resistance and due to the normal aging of the battery.

The Zener Diode eliminates this by maintaining a constant line voltage. In our particular instrument it is six volts. Of course we must use a battery in excess of six volts. Nine volts is a good value. I have found that used transistor radio batteries still have enough life in most instances to last for many tests.

One of the main requisites of a noise generator is that it must be shielded throughout. Therefore we must give some thought as to the placement of the various components.

A Mini-box 2¼ x 2¼ x 4 is an ideal size. As for a connector I used the SO-239 coaxial. I find that this connector allows more flexibility



than any other. If a direct connection to the receiver is desired merely attach it through the double connector type DKF-2 made by Dow Key. On the other hand if it is desired to have the controls of the noise generator close at hand merely connect a length of Coax of eighteen inches or so. I haven't been able to discover that it has affected any measurements to any degree.

In the construction of this noise generator just remember a few basic rules. Keep all connections as short as possible. The noise diode and bypass condenser and resistor (50 or 75 ohms as the case may be) as close as possible to the output plug. Remember to use pliers to absorb the heat when soldering the leads of the diodes.

To mount the silicon diode, which has one large end and one small, we must improvise to a certain extent. For the small end a lug from one of the old tube sockets will do. For the large end use a small fuse clip.

Don't be too fussy about the variable resistor. For most purposes any value from 10M up to 50M can be used.

The battery you choose will determine the manner of mounting.

No need to give detailed instructions as to the use of this noise generator. There are ample instructions to be found in various magazines as well as handbooks.

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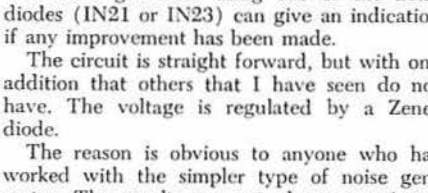


To avoid excess wear and tear on the zener diode and the battery a 200 ohm resistor should be inserted between the 9 v battery and S1.

Parts List

2—¼ x 2¼ x 4 Minibox
Bt—9 volt battery
Cr1—6 Volt Zener Diode
Cr2—IN 21 or IN 23 Silicon Diode
R1—10M-50M Variable
R2—51 ohm or 75 ohm (according to your line)
C1—.001 to .005 disk ceramic
S1—S.P.ST. this may be on your variable resistance
P1—So-239

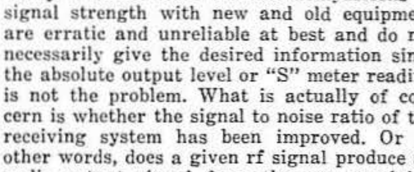
A CRYSTAL DIODE NOISE GENERATOR

Karl Tipple W5TEV

Most amateurs who do very much operating at the higher frequencies where receiver sensitivity rather than QRM often determines success eventually come to the conclusion that their present receiving equipment is not as sensitive as would be desirable and that a change is in order. And once that change has been made, whether it takes the form of a new converter or modification of existing rf stages, one nearly always wonders whether the new really *is* better than the old. Comparisons of signal strength with new and old equipment are erratic and unreliable at best and do not necessarily give the desired information since the absolute output level or "S" meter reading is not the problem. What is actually of concern is whether the signal to noise ratio of the receiving system has been improved. Or in other words, does a given rf signal produce an audio output signal from the new receiving equipment that is louder in comparison to the background noise than did the same input signal with the original receiving equipment. If it does, the noise figure of the new receiving equipment is smaller (better) and it should be possible to copy a weaker signal than before.

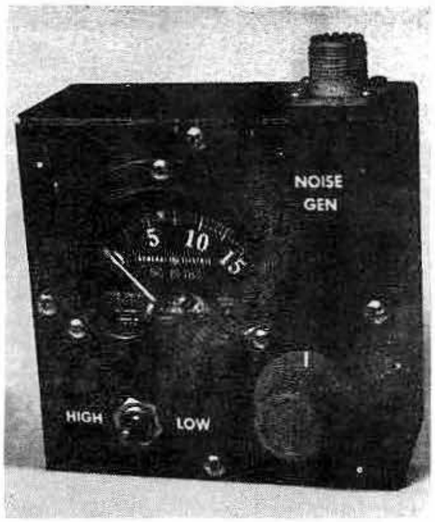
Unfortunately few of us own or have access to a signal generator of the proper frequency range, with an accurately calibrated attenuator and shielded output, for making the type of measurements mentioned above. For the majority of amateurs something less expensive and more readily available is needed. A crystal noise generator, which can be constructed for a few dollars and which will enable anyone to make before and after comparisons of noise figure, is such a device.

Briefly, the theory behind the use of the noise generator follows. The sensitivity of a receiver is highly dependent on the ability of the rf stages to amplify a weak signal as much as possible while adding a minimum amount of noise to the signal. Noise of this type will



R1 • 10,000Ω POT - - LOG TAPER PREFERRED
R2 • 1/2 WATT NON-INDUCTIVE RESISTOR EQUAL TO LINE IMPEDANCE

FIG. 1



be heard at the receiver output as a familiar hiss or "rushing" sound. Now, if an external source of broadband or white noise (random noise independent of frequency) is connected to the receiver antenna terminals, an increase in noise or hiss will be noted at the receiver output. And if the noise generator output is adjusted to provide exactly twice as much receiver output noise as existed before the application of the noise generator, then the generator must be providing a noise signal equal to that generated in the receiver. Thus, if the receiver can be modified so as to reduce the noise generator signal required to double the receiver noise output, the noise figure of the receiver will have been improved.

A noise generator of the type described in this article can not be used for measurement of absolute noise figure without additional calibrating equipment. It can, however, be used for *comparison* of noise figures. It enables one to determine whether a receiver really has been improved and it can be used to determine which of a number of possible modifications will yield the best results in terms of minimum noise figure (maximum sensitivity). Use of the device will be discussed in more detail later.

A basic noise generator circuit is shown in Fig. 1. The noise is produced by CR1, a silicon diode of the 1N21 or 1N23 variety. These diodes have been widely available on the surplus market for several years. They are also readily available new at small cost; however as will be explained later, it may be desirable to use a surplus diode rather than a new one.

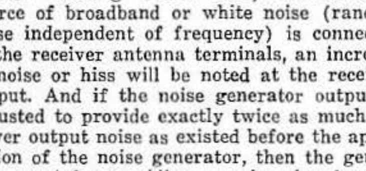


FIG. 2

R1 = 10,000 ohm pot—log taper preferred
R2 = 1/2 watt non inductive resistor equal to line impedance
Other parts same as Fig. 1

The current supplied to the diode from the battery and therefore the noise generated by the diode is determined by the setting of R1. The best value for R1 is necessarily a compromise since in its maximum resistance position it must limit the current to a low value but it must also not change resistance too rapidly at the low resistance end of the range or the normal operating range of the instrument will be limited to only a few degrees rotation of the R1 shaft. A 10,000 ohm log taper pot should prove satisfactory.

The value of R2 should be about the same as the transmission line impedance. A good value might be 56 or 68 ohms, although if it is desired to use the noise generator with equipment which normally operates from higher impedance lines, a larger value should be selected for R2. In this case one might compromise with a value of 100 ohms. C1 serves as bypass capacitor and may be either mica or disc ceramic.

A more elaborate arrangement was used in the construction of the unit shown in Photo. 3. A schematic of this generator appears in Fig. 2. Here a tapped battery (2 pencells) was used to minimize the range to be covered by R1. It should also be noted that the diode is shown reverse biased in Fig. 2. Many of the surplus diodes available have very poor reverse resistances, which will allow reverse bias operation, and when operated under these conditions will generate considerably more noise for the same bias current than when operated in the more conventional configuration shown in Fig. 1. The diode must have a reverse resistance of only a few thousand ohms or less if it is to work successfully in the reverse bias connection. Therefore unless the reader can obtain some surplus diodes and select one with a low reverse resistance, it will probably be necessary to operate the diode forward biased and to use the higher battery voltage of Fig. 1.

The meter range depends upon the battery voltage and the resistance of the diode in whichever connection it is used. The meter used in Fig. 2 was a 0-4 ma surplus meter. However, if the diode is operated in the forward biased connection a meter of somewhat higher current rating will probably be needed. Therefore, it is suggested that a low range meter be obtained and if more than full scale current is required for the diode to develop sufficient noise, a shunt resistance can be placed across the meter terminals to extend the meter range. An inexpensive meter can be used since all that is needed is a relative indication of current.

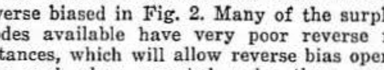


FIG. 3

For those not familiar with the IN21-1N23 type diodes it might be mentioned that they have no wire leads. The anode connection is a brass shell on one end of the unit and the cathode connection is a brass pin at the other end. Although external connecting wires might be soldered to the brass ends, there is danger that the diode will be over heated and destroyed by such techniques. It is safer to make connections by clamps made from small plate or grid caps or fahnstock clips.

It should be evident from the above discussion that there is nothing critical about the construction of a noise generator of this kind and that a number of different circuit variations are possible. Even if the device were constructed entirely of new components the cost should be less than $8 and with a little ingenuity the cost can be reduced substantially through the use of surplus parts.

Perhaps use of the noise generator can best be illustrated by considering an example of noise generator application. Suppose that you want to use either one of two available 6 meter converters with your low band receiver and that you wish to determine which converter will provide the best weak signal reception. A test set-up is shown in Fig. 3.

The ac voltmeter is used to measure the audio output of the receiver and may be either a multimeter or a VTVM. It can be connected across the speaker terminals or across the headphone line. Higher voltages can generally be obtained from the headphone output and this connection will probably have to be used if a multimeter without a very low ac range is used.

The measurements can be started by measuring the ac noise output voltage from the receiver with the noise generator turned "off". Then the noise generator should be turned "on" and the generator level adjusted until the output meter reading has doubled. At this point a note should be made of the noise generator setting. The above procedure can now be repeated with the second converter connected to the receiver. Whichever receiver-converter combination requires the smaller noise generator current setting to double the noise output is the combination that will provide the best weak signal reception.

The noise passed by the receiver is a function of the bandwidth of the receiver. Also the reading given by a particular output meter is dependent on its bandwidth. Therefore the bandwidth of the receiver should not be changed during measurements and the same output meter should be used thoughout a set of measurements.

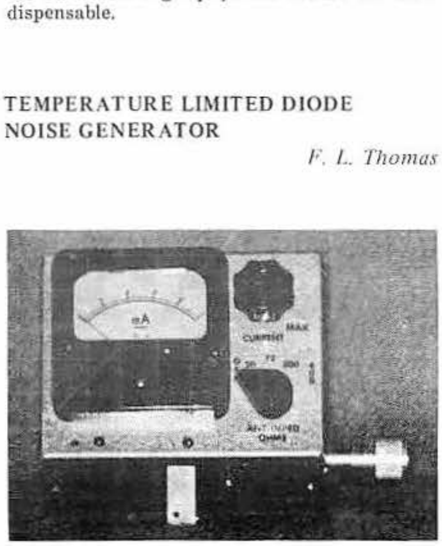
The technique described above can also be used to determine which of a number of rf amplifier tubes will give the best performance. The noise generator can be used for alignment of rf stages.

For the man who constructs his own converters or receivers the device is a tremendous boon since such adjustments as determining the optimum antenna to grid coil coupling can be made simply by adjusting for maximum increase in noise when the generator is switched "on". (This technique gives the same results as adjusting for minimum noise generator setting to double noise output and it is a bit easier to use when adjustments must be made.) If the input circuit uses a single tapped coil instead of two coils, the best tap position can be determined.

The uses mentioned above are only a few of the possible applications of this noise generator, and for the amateur who constructs his own receiving equipment the device is indispensable.

TEMPERATURE LIMITED DIODE NOISE GENERATOR

F. L. Thomas



Recently I was confronted with the necessity for a good noise generator. All of the noise generator designs available in any of the

amateur publications at hand were of the crystal diode type. The disadvantage of this type of instrument lies in the fact that the current through the diode has no simple relation to the noise output. Unless expensive calibration equipment is on hand this type of generator is useful only on a comparative basis. Consequently it was decided that a temperature limited diode noise generator would be built.

The noise output of a temperature limited diode noise generator is simply related to the current flowing through the diode.[1] The noise figure of a receiver may be calculated directly from the magnitude of the current by the following equation:[2]

Noise figure in db.=10 log (20 I R)—(1)

Where I=current through temperature limited diode required to make the noise output power of the receiver double the value it was with no current through the diode.

R=antenna impedance

The actual noise generator is quite simple, consisting of half a 6AL5 with a milliammeter in the cathode leg and the appropriate resistance for the antenna circuit connected to the plate by means of a selector switch. The heater current is controlled by a 20 ohm potentiometer in series with the heater. The unit is battery operated for convenience. High current capacity, small sized mercury cells are used throughout. The whole unit is contained in a 3" x 4" x 5" Minibox.

Construction

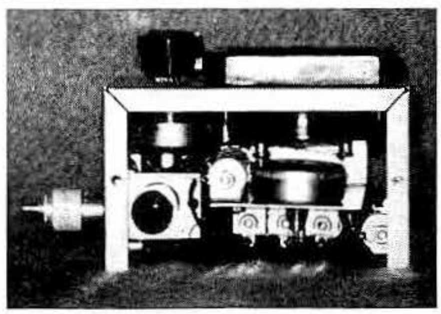
The resistors are mounted on the switch, making the leads as short as possible. The tube socket is mounted on a small bracket screwed onto the side of the chassis, placed so that the distance from the switch is a minimum. The meter calibration potentiometer and the heater supply battery holders are mounted on another bracket placed over the meter as shown in the photograph.

Operation

To use the generator it is connected to the receiver antenna terminals, the AVC is turned off, and the audio output is measured with the generator off. The generator is then turned on and the current through the diode is increased until the power output is double what it was before. At this point the voltage output will only be 1.41 times the original. The current necessary to give this noise increase is noted and the noise figure calculated according to equation (1), or estimated from the figures given in Table I.

Noise Figure in db.	Current, ma., for antenna impedance of:			
	50 Ω	72 Ω	300 Ω	600 Ω
2	1.40	1.15	-	-
4	2.25	1.80	0.42	-
6	3.55	2.85	-	-
8	5.65	4.50	1.05	0.53
10	8.85	7.15	-	-
12	14.2	11.3	2.65	1.32
16	-	-	6.65	3.30
20	-	-	16.6	8.42

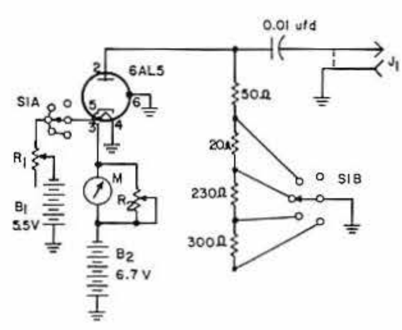
The unit described is useful for noise figures up to 13 db at 72 ohms. For higher noise figures a higher current capacity diode and a higher heater voltage and current supply is required, necessitating an ac operated power supply. With a suitable power supply a 6X4 may be satisfactorily operated up to a noise figure of about 22 db. In both cases the maximum noise is obtained by passing more



than the allowable average current through the diode. Consequently readings at these extremes should be made and the current lowered again in only a few seconds, or damage to the diode will result.

Table I shows the current readings for various noise figures with different antenna impedances.

The generator will operate satisfactorily up to at least 50 mc, and probably considerably higher.



B1—four Mallory RM12 or RM12R in series (lifetime of this circuit should be greater than 10 operating hours)
B2—Mallory TR-135R
M—0-1 ma (Lafayette TM-60 or equivalent)
R1—20 ohm potentiometer
R2—20 ohm Potentiometer
J1—coax connector
S1—DP 5 pos miniature rotary switch

Editor's Note: By substituting flashlight batteries for the mercury cells and a 20 mA meter instead of the 1 mA meter with a shunt across it, the cost of construction can be greatly reduced.

REFERENCES

1. **Radiotron Designers Handbook**, fourth edition, page 1307, reproduced and distributed by RCA Victor Division, Radio Corporation of America, Harrison, N. J., 1953.
2. **Radio Engineering Handbook**, fifth edition, page 19-10, Edited by Keith Henney, Published by McGraw-Hill Book Company, 1959.
3. Terman, F. E., **Electronic and Radio Engineering**, fourth edition, Published by McGraw-Hill Book Company, 1955.

CALIBRATED NOISE GENERATOR FOR 432

Hank Olson W6GXN

As pointed out in previous articles—the temperature-limited noise diode is the best tool for measuring the sensitivity of one's receiver. The measurement made with this device is "noise-figure" or "noise-factor" and this is the magic number by which you can compare your VHF or UHF receiver with Joe's down the street, or Sam's in Massachusetts. These measurements will be comparable between any two receivers because bandwidth, type of detector, and other miscellaneous features (different for each receiver) do not affect the measurement, if it's carefully made (that is, if one's measurement of 3 db power increase, when the diode is turned on, is true).

Past amateur articles on noise-diodes and their use in noise-factor measurement have only shown how to construct units for up to about 200 mc. The noise generators described previously, for amateur use, have used the 5722, the diode wired 24G (3C24), or the diode wired 801A, as their tungsten-filament diodes. The 15E and 01A have also been used occasionally as diode-wired triodes, too. Commercial UHF noise generators use a variety of tungsten-filament tubes, all of which are a bit expensive for most hams. If you can lay your hands on one of these tubes, used or otherwise surplus, by all means employ it in your noise generator. Table 1 is a list of such gems.

Philco:	L1262A
RCA:	R6212
Bendix:	6144
Marconi:	CV2171

Table I

The tube I used is a triode, a Western Electric 708A, originally designed for grounded-grid UHF amplifier service. The grid and filament are used as the diode elements, ignoring the plate altogether; the plate, if used, could only increase transit time and shunt capacity. The tube is used, as it was intended to be used, with the metal shell (grid) grounded. The 50 Ω load is connected in the filament circuit; the filament power is fed in by means of a concentric inductor, which also tunes out the stray capacity of the tube.

RF Circuitry.

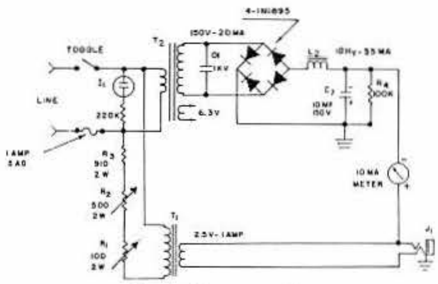


Fig. 1. Power supply.

C_1, a small "tweaker," adds in a tiny additional capacity to make adjustment to 432 mc easier; it makes tuning to anywhere in the 420 to 450 mc band possible. L_1 is constructed of a 1⅞" length of ⅛" copper tubing and has a piece of No. 20 teflon insulated wire inside it. The use of teflon insulated wire is only necessary because teflon will withstand the heat of soldering.

The effective circuit, then, is as in Figure 2.

At 432 mc, if $Cgk + C_1 = 3$ mmfd, then L must be 0.04 μh to be parallel resonant. The reactance of either $Cgk + C_1$ or L_1 is about 100 Ω, so the system has a Q of ½, and hence will be rather broad in its noise output spectrum—just as we want it to be.

The WE 708A tube was recently available from a Los Angeles surplus emporium at the price of 39 cents each or ten for a dollar. We bought a buck's worth, figuring some would be NG, but all were perfect and saturated well. One was lost in initial test, when we applied too much filament voltage; it was subsequently hack-sawed open to find out the details of its construction and to confirm connections. The details learned are presented in Figure 3 along with its saturation curve.

The filament is a single, fine, straight, tungsten wire through the grid helix. The grid helix is perhaps 1/16" diameter and is welded every turn to the shell. All this adds up to: good cylindrical diode configuration, close cathode-grid spacing to cut down transit time, and low grid to case inductance. In short, we have a nearly ideal noise diode for a dime a piece.

Construction details: The rf section of the generator is constructed on an aluminum plate bent into an L, the WE 708A protrudes through a 1⅜" round hole to expose its filament pins next to where the UG58A/U connector is mounted on the other side of the L. The WE 708A is held in place by five 8-32 binding-head screws that are tapped into the plate. The UG58A/U has four 200Ω, ½ w resistors soldered to it each at 90° to its neighbors to form a less inductive load, approximating a resistive sheet. These resistors are

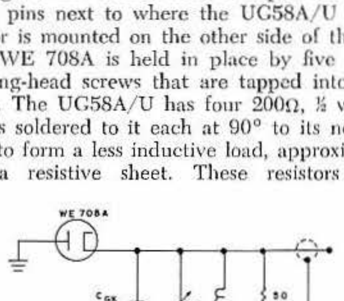


Fig. 2. Basic noise generator circuit.

soldered to the UG58/U before it is mounted to the aluminum sheet to make soldering easier (less heat required). Then L_1 is formed and soldered from the WE 708A filament pin to C_3. The center filament lead of L_1 is fed through and soldered to the other filament pin and to C_4. C_2 is then soldered in; be sure this is the type called for or a similar low inductance stand-off ceramic. The rest is straight forward. Diode and power supply were each built in an LMB 141 box chassis. The details of wiring the diode circuitry are shown in Fig. 4.

A word about R_1 (the "fine" adjust) is worthwhile. Make *sure* this one is a 2w type A.B. (ohmite) molded carbon pot, if not both R_1 and R_2. This will make smooth diode-plate current adjustment easy; a wire wound pot will cause the plate current to vary in steps because of the effect of the pot's sliding

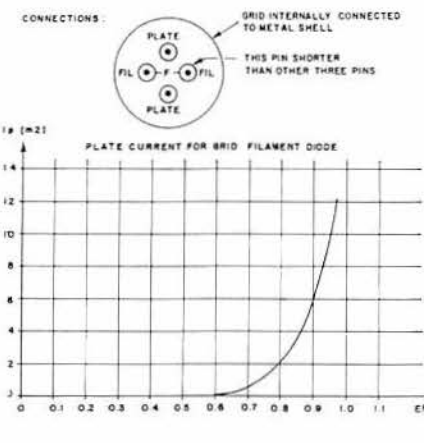


FIG 3

Fig. 3. Connections of 708A and graph of relationship between "plate" current and filament voltage.

contact sequencially contacting each wire (the same applies if you use a Variac).

To align on 432 mc, C_2 is temporarily removed and a UHF grid dip meter coupled to L_1, loosely. C_1 is adjusted for a dip at 432 mc. Then C_2 is reinstalled, and we should be ready for receiver checks.

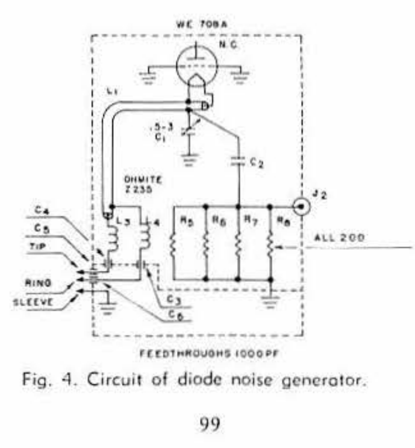


Fig. 4. Circuit of diode noise generator.

The above noise generator was compared with a Hewlett Packard 343A noise diode using my own 432 mc converter as the "to be measured" device. The results showed less than 0.5 db difference.

The author wishes to thank Gene Howell, W4RLU, for his photography of the unit.

ANOTHER WAY TO MEASURE NOISE FIGURE

Jim Kyle K5JKX

Many times it's been said, but it can always bear repeating. Noise figure is probably the least-well-known measurement in any amateur station.

At least a part of the difficulty with noise figure lies in the means usually employed to measure it. While it's not too difficult to figure out the power input to your final, or even the power *output* (often a surprisingly different figure), measurement of receiver noise figure tends to be a complicated and somewhat inaccurate process at best. It requires special equipment, and even then may be no more accurate than plus-or-minus 100 percent.

The classic means of measuring noise figure is to use a noise generator and crank in additional noise until receiver output is doubled. This means, of course, that the noise generator output is then exactly equal to the original noise, and if the noise-generator output is accurately known then the original noise is also known. All this has been gone into in detail in another article.

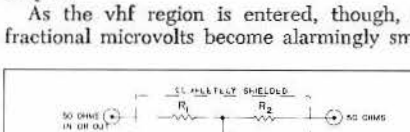
However, a noise generator with accurate calibration isn't so easy to come by, and an inaccurate noise generator doesn't do much good for measurement purposes (although it's fine for tune-up).

There *is* another way to do it, which is actually much more in line with amateur practice. This other way also requires some test equipment, but it might be more easy to come by.

Before we get into the details of the "other way" to measure noise figure, let's take another look at the reason for using noise-figure measurement as a yardstick for receiver sensitivity in the first place.

To start, we're really interested in the answer to the question "How weak a signal can I hear?" In the 3-30 mc range, the question can be answered directly—how many microvolts must the receiver have to give readable output?

As the vhf region is entered, though, the fractional microvolts become alarmingly small.



DB Loss	R1, R2	R3
3	8.2	150
6	16	68
9	24	39
20	39	10

All resistors composition, ½ watt, 5%

Fig. 1. Construction of T-pads

Somebody figured out that most of the problem lay in the receiver's own internal noise, and came up with the idea of a "perfect" receiver which would have no noise at all. This is a noise figure of 0 db. Now by comparing existing receivers to this perfect ideal, and comparing the internal noise in db, we had a way of discussing receiver sensitivity.

Since we're now talking about noise, which is equally present at all frequencies throughout the spectrum, we can see that the amount of noise present in a receiver's output is at least partially determined by how much of the spectrum we are looking at. A broad receiver has more noise output than a narrow one, all other things being equal. If you don't believe it, fiddle with the selectivity switch on your own rig and listen to the change of noise output.

This dependence of noise on bandwidth is another reason for using noise figure as a comparison. The *actual* amount of noise is cancelled out in the comparison, leaving only the relative amounts of noise in the "perfect" receiver and the receiver under test to be measured.

When all this became established, nobody

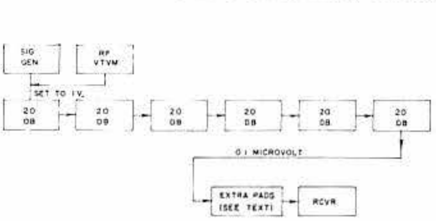


Fig. 2. Test set up.

was paying much attention to receiver bandwidth and it was felt that a true determination of the effective noise bandwidth of a receiver was much more complicated than the comparison measurement. However, in these days of SSB and special filters, that's not so true any more.

As you may have guessed by now, the "other method" of determining noise figure depends on a microvolt measurement and knowledge of the receiver's effective noise bandwidth. The only reason for converting the results back to noise figure is to allow comparison with measurements made in the more conventional manner.

With typical ham measurement techniques, the results won't be of National-Bureau-of-Standards accuracy. However, if you're reasonably careful, results using this method will be at least comparable in accuracy to those made with a homebrew noise generator. Ready? Let's go:

You'll need two items of test equipment (only one if you're really lucky). These are an rf signal generator covering the desired frequency range on fundamental output, and an rf VTVM reasonably accurate at the desired frequency. If you have access to a "microvolter" or similar laboratory signal generator, you won't need the VTVM.

In addition, you'll need a whole handful of 50 ohm T-pads; these can easily be put together in a hurry by following the schematic in Fig. 1. You'll probably need about 8 20-db pads, as well as one each in 3-db, 6-db, and 12-db values.

Turn on both the receiver and the signal generator and let them warm up. For protection against any leakage from signal-generator to receiver through the power lines, it's best to supply them from separate circuits and to use a power-line filter such as that used to eliminate rf interference between the power line and the unit.

Connect a string of six 20-db pads to the signal-generator output as shown in Fig. 2, and adjust output of the signal generator to 0.1 volt. If you have a microvolter or equiv-

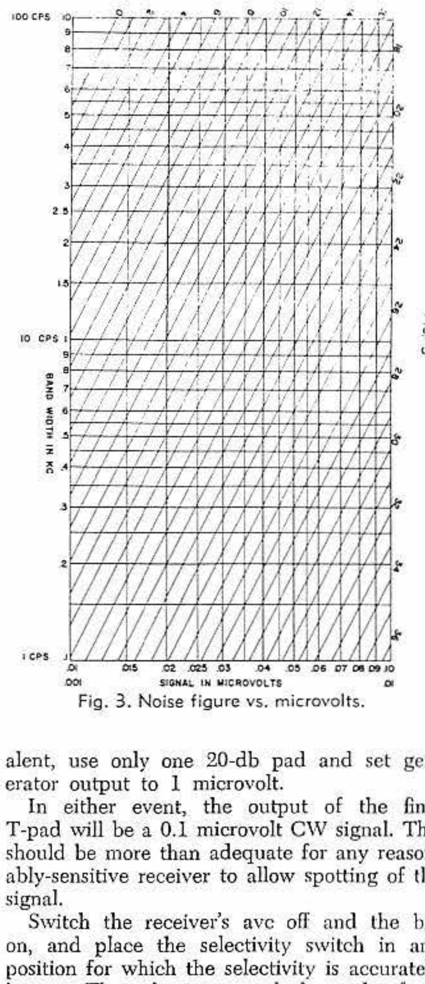


Fig. 3. Noise figure vs. microvolts.

alent, use only one 20-db pad and set generator output to 1 microvolt.

In either event, the output of the final T-pad will be a 0.1 microvolt CW signal. This should be more than adequate for any reasonably-sensitive receiver to allow spotting of the signal.

Switch the receiver's avc off and the bfo on, and place the selectivity switch in any position for which the selectivity is accurately known. The selectivity marked on the front panel will not be the effective noise bandwidth, but you can use it as a starting point to guesstimate the noise bandwidth. If your receiver uses a mechanical filter or other device with approximately the same skirt selectivity, effective noise bandwidth will be about 1½ times the bandwidth marked on the front panel. If it is one of the older types with reasonably broad skirts, noise bandwidth will be about 3 times the marked value. Both these correction factors are approximate, of course; if you have any means of measuring effective noise bandwidth, use it instead.

For a start, use a fairly broad selectivity position; this requires more signal and makes things a bit easier.

Now tune in the signal from the generator, leaving gain controls at maximum but tuning for maximum signal strength just as if it were the new state you need. The 0.1-microvolt signal should be easy to find.

Next step is to reduce the generator output by hooking in additional T-pads until you locate the point of "minimum discernible signal." The 3, 6, and 12 db pads may be hooked up in series in any combination to give you from 3 to 24 db additional attenuation in 3-db steps. Using another 20-db pad will give you from 20 to 44 db more attenuation, and the signal is sure to become too weak to copy before you reach 44 db below one-tenth of a microvolt!

The point of MDS is approximately equal to a 0-db signal-to-noise ratio for most of us, and is considerably easier to determine than would be a true output S/N ratio. When you find this point, record the db below 0.1 microvolt and the selectivity (in kilocycles) used.

Now switch to a different bandwidth on the receiver and repeat the test. Record its results also. For maximum accuracy, repeat each of the tests 10 to 12 times and average the result.

The signal level in microvolts corresponding to db below 0.1 microvolt is given in Table I. Locate it there and move to Fig. 3, the graph of signal versus bandwidth by noise figure.

Enter the graph from the side with effective noise bandwidth, and move across until you intersect the line corresponding to signal level in microvolts. The diagonal lines are noise figure; if one passes through the intersection point, read noise figure in db from it. If not, interpolate between the lines.

In reading Fig. 3, use the 10 kc-100 cps scale with the .01-.1 microvolt scale, and the 100 cps-1 cps scale with the .001-.01 microvolt scale. If your bandwidth-signal level combination falls off the graph to the left, use the

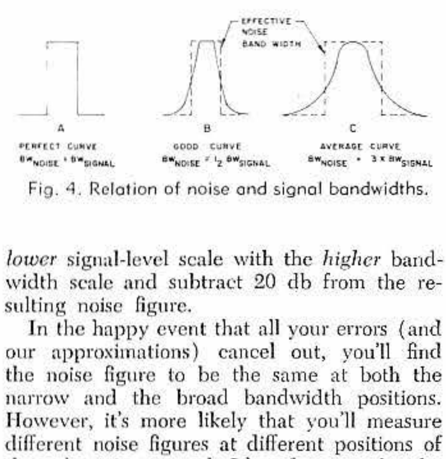


Fig. 4. Relation of noise and signal bandwidths.

lower signal-level scale with the *higher* bandwidth scale and subtract 20 db from the resulting noise figure.

In the happy event that all your errors (and our approximations) cancel out, you'll find the noise figure to be the same at both the narrow and the broad bandwidth positions. However, it's more likely that you'll measure different noise figures at different positions of the selectivity control. It's safest to take the highest noise figure measured as being closest to correct, but you can average them if you prefer. Either way, you will probably be within 1 db of the real figure—and this is as accurate as most noise-generator techniques can be, also.

That completes the measurement, but before we wind this up let's take a more detailed look at the idea of "effective noise bandwidth" which is such a key part of this measurement technique.

Most of us are familiar with the idea of a "perfect" curve for receiver selectivity such

as that shown at A in Fig. 4. Here the receiver has equal response over the desired band, and response drops to zero at the band edge. Such a curve is said to have a shape factor of 1, and is of course impossible to achieve in practice.

Now back to noise; it's spread out equally over the spectrum. A noise bandwidth of 1000 cycles per second contains 10 times as much noise as one of 100 cps. Thus "noise bandwidth" inherently has a shape factor of 1.

Since such a shape factor is impossible to achieve, it follows that "noise bandwidth" and actual receiver bandwidth must differ. If receiver bandwidth is measured at the —60 db points, the noise bandwidth will always be smaller than this receiver bandwidth. If receiver bandwidth is measured at the points where response drops 1 db below peak, the noise bandwidth will always be greater.

The mathematical expression for noise bandwidth is an integral equation involving differential gain, which is a cumbersome thing to solve. In general, the noise bandwidth of a receiver is said to be approximately equal to the bandwidth between points which are 3 db down from peak response.

In practice, if the shape factor (6 to 60 db) of the receiver is 2, the effective noise bandwidth will be approximately 1.3 times the 6-db bandwidth. If shape factor is between 2 and 10, noise bandwidth will be approximately equal to the square root of the shape factor (6 to 60 db) times the 6-db bandwidth. Few receivers have shape factors greater than 10.

db BELOW 0.1 MICROVOLT	MICROVOLTS
3	.07
6	.05
9	.035
12	.025
15	.018
18	.013
20	.01
21	.009
23	.007
24	.0063
26	.005
29	.0035
32	.0025
35	.0018
38	.0013
41	.0009

Table I.

The approximations quoted earlier (1.5 times marked bandwidth for SSB-selectivity receivers, 3 times marked bandwidth for others) are based on these relations. If you're really interested in calibrating your receiver's noise bandwidth for using this measurement technique, however, you might take a converter and have it measured for noise figure by the generator technique, then run this technique backwards to determine the effective noise bandwidth of your receiver in each position of the selectivity control.

The technique described here, incidentally, assumes that no audio filters are used following the detector. If they are, all results are off, since the effective noise bandwidth will have been changed in an unpredictable manner by the audio filters.

However, you can remove the audio filters from the hookup for measurement purposes, determine noise figure, then return the audio filters to the circuit and run the measurement backward to find out your effective noise bandwidth with filters present. Don't be surprised if it comes out in the region from 1 to 10 cycles per second; a good audio filter can work wonders with weak-signal reception.

For additional details on this technique of measuring noise figure, you can consult Reference Data for Radio Engineers, 4th edition, published by IT&T and available from Radio Bookshop, or any good radar text.

Chapter IX

Attenuators and Dummy Loads

LOW POWER ATTENUATORS FOR THE AMATEUR BANDS

George Daughters WB6AIG
Will Alexander WA6RDZ

In the evaluation of rf amplifiers, filters and many other devices, a variable attenuator is indispensable. This article describes attenuators built and tested by the authors. These attenuators are flat from dc to over 50 MHz and usable to over 450 MHz. They use low cost parts, are very simple to build, and are more accurate than ordinarily required in amateur applications.

The basic attenuator section is the symmetrical pi shown in **Fig. 1**. Resistance values are given by the relations:

$$R_1 = R_s (\sqrt{K} + 1)/(\sqrt{K} - 1)$$
$$R_2 = R_s (K - 1)/(2\sqrt{K})$$

where R_s is the characteristic impedance of the pad (equal to the source and load impedance) and K is the attenuation factor, P_{in}/P_{out}.

Resistor values for the most commonly used impedance (50 ohms) are shown in **Table 1.**

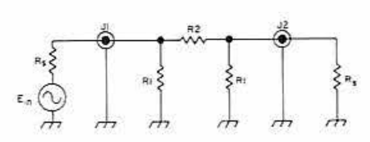


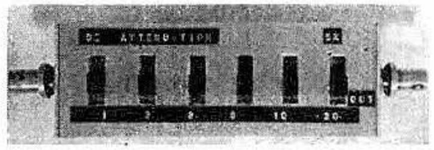
Fig. 1. Basic pi-network attenuator section.

Nominal attenuation in dB	R_1 in ohms	R_2 in ohms	Calculated attenuation in dB	Measured attenuation in dB
1	910	6.2	1.1	1.1- 1.2
2	430	12	2.1	2.1- 2.3
3	300	18	3.0	3.2
6	150	39	6.2	6.3- 6.6
10	91	68	10.2	9.6-10.1
20	62	240	19.6	19.5-19.7

Annenuation measured at 50 MHz and lower.

Table I. Resistor values for 50-Ω attenuators.

Notice that the use of standard value 5% half watt composition resistors allows accuracy within 1 dB of the calculated value of attenuation and within 1 dB of the desired nominal value.



Amateur low-power attenuator made from inexpensive slide switches, 5% resistors and fiber glass, copper-clad board.

The attenuators are built in small channel boxes made of copper-clad etched circuit board material. Aluminum channel boxes commercially available would probably work equally well. Small, inexpensive DPDT slide switches (H. H. Smith No. 518 cr equivalent) are soldered directly to the copper board and the resistors are soldered to the switch terminals (which have been cut short) with the shortest leads possible.

Two wiring variations have been tried, one with the series resistors (R_2) mounted between the switch wiper contacts (type B), and one with all resistors connected to the attenuator in terminals (type A). See **Fig. 2** and the photo of the interior of the attenuator. It was found that the latter arrangement, type A,

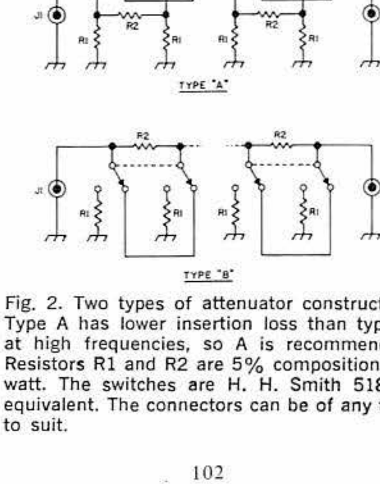
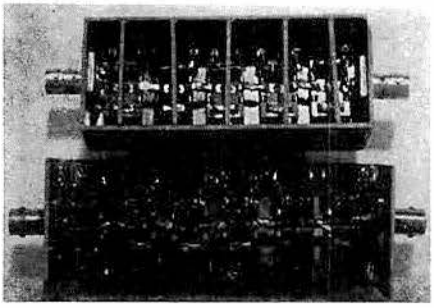


Fig. 2. Two types of attenuator construction. Type A has lower insertion loss than type B at high frequencies, so A is recommended. Resistors R1 and R2 are 5% composition, ½ watt. The switches are H. H. Smith 518 or equivalent. The connectors can be of any type to suit.



Details of attenuator construction. The top style, with complete shielding, is recommended.

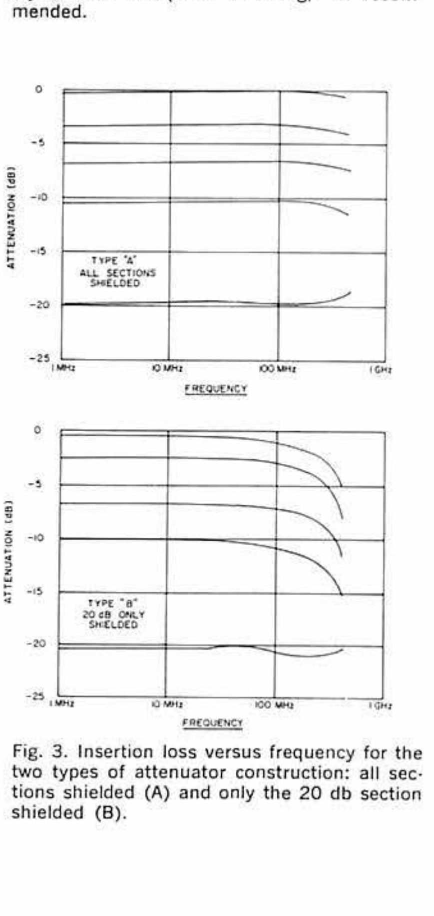


Fig. 3. Insertion loss versus frequency for the two types of attenuator construction: all sections shielded (A) and only the 20 db section shielded (B).

provided less insertion loss than the former at high frequencies, so this type of construction is recommended. Also note that dividing shields are desirable between input and output elements of a single section. These shields prevent capacitive feedthrough at the high frequencies, and are desirable on the high attenuation sections (anything over 10 dB) even at low frequencies. On the low attenuation sections, very little difference is evident below VHF. See **Fig. 3** for the attenuation of the attenuators up to over 450 MHz. Building attenuators with greater than 20 dB attenuation per section by this method is not recommended for high frequency use.

S-UNIT ATTENUATOR

Ed Lawrence WA5SWD

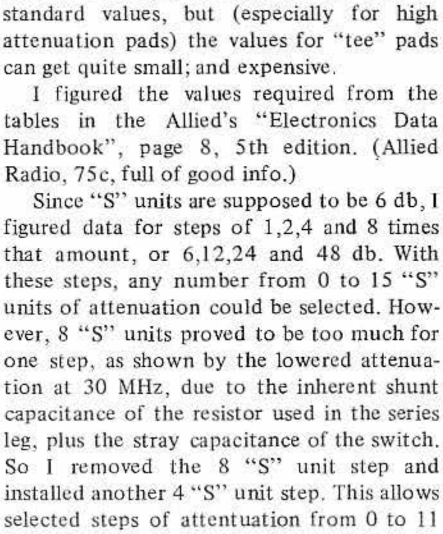
Since the topic of "S meters" is a popular one among radio amateurs, a lot of time is spent describing these devices, usually along the lines of how generous or "Scotch" the meters are at the QTH of the parties in the QSO. After a few such QSO's, I decided to build an attenuator, calibrated in "S" units. My aim was to attain an accuracy of 1 db or better, using 5% ½w resistors and simple construction so it would be easy to duplicate.

As a sidelight, I started out by calculating both "tee" and "pi" pads, and used "pi" because all values of resistance are close to standard values, but (especially for high attenuation pads) the values for "tee" pads can get quite small; and expensive.

I figured the values required from the tables in the Allied's "Electronics Data Handbook", page 8, 5th edition. (Allied Radio, 75c, full of good info.)

Since "S" units are supposed to be 6 db, I figured data for steps of 1,2,4 and 8 times that amount, or 6,12,24 and 48 db. With these steps, any number from 0 to 15 "S" units of attenuation could be selected. However, 8 "S" units proved to be too much for one step, as shown by the lowered attenuation at 30 MHz, due to the inherent shunt capacitance of the resistor used in the series leg, plus the stray capacitance of the switch. So I removed the 8 "S" unit step and installed another 4 "S" unit step. This allows selected steps of attentuation from 0 to 11 "S" units.

Here are the values I calculated, and the actual values used, based on 51 ohms. The steps are switched in series, as required for the desired attenuation.



Looking inside the attenuator.

Resistance Values for 51 Ohm Attenuator:

		R1		R2	
"S" units	DB	ideal	actual	ideal	actual
1	6	154	150	38	39
2	12	85	82	96	100
4	24	58	56	405	390
8	48	51.5	51	6400	6800

After the attenuator was completed, the attenuation was measured at 3 kHz and at 30 MHz. With the test equipment available it was possible to measure more accurately at 30 MHz than at 3 kHz. Below is the data from the tests.

Atten Step "S" units	DB	Predicted atten DB	Measured at 3 kHz	Measured at 30 MHz
1	6	6.2	6.0	6.02
2	12	12.3	12.2	12.16
4	24	23.3	24.2	24.05
8	48	48.5	47.5	39.11

Now if we want to make an educated guess as to how far up we can expect good results, say 1 db error out of 24 db, then we can use the measured error in the 48 db step to calculate the capacitance across the series leg, and from that calculate the frequency where the 1 db error will occur. Go through the math if that is how you get your kicks, or take my word for it. It comes out to about 2 pF. And this will cause a reduction of 1 db at about 220 MHz. And since the resistor is

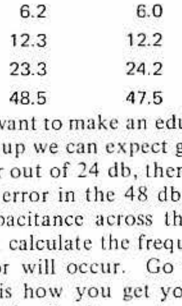
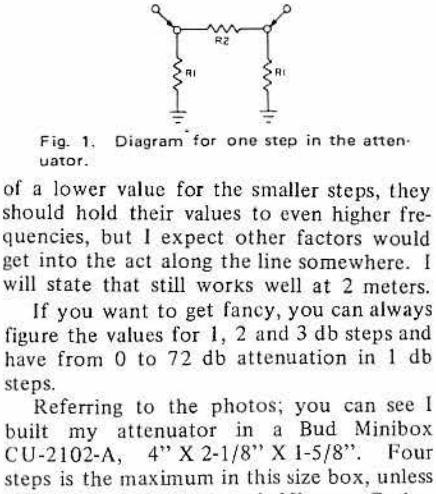


Fig. 1. Diagram for one step in the attenuator.

of a lower value for the smaller steps, they should hold their values to even higher frequencies, but I expect other factors would get into the act along the line somewhere. I will state that still works well at 2 meters.

If you want to get fancy, you can always figure the values for 1, 2 and 3 db steps and have from 0 to 72 db attenuation in 1 db steps.

Referring to the photos; you can see I built my attenuator in a Bud Minibox CU-2102-A, 4" X 2-1/8" X 1-5/8". Four steps is the maximum in this size box, unless different switches are used. Mine are Cutler-Hammer 7592K6. The shielding was made from transformer strap, but could be any soft copper available. Try a Hobby Shop and get the thin sheet that is used for embossing if all else fails.



Front panel showing the switches for the various steps of attenuation.

Here are some of the uses an attenuator of this type is suited for:

Checking receiver "S" meter calibration.

Attenuating signals to aid in peaking receivers and converters.

Calibrating diode voltmeters for *rf* measurements.

Checking antenna gain. Or gain of that outboard *rf* stage.

P. S. My "S" meter lies, just as I thought!

THE EVER-USEFUL T-PAD

Jim Kyle K5JKX

Most of us have transmitters; let's hope that an equal number of us have receivers also. Antennas and microphones are usual station accessories, with a few determined diehards here and there clinging to the trusty old key. But how many of us have much in the way of test equipment?

Now and then somebody pops up with a VOM, and occasionally you can even find an operator who uses a scope. But the kind of special-purpose test gear you find in a well-equipped laboratory is almost always absent in the ham shack.

Which is more or less as it should be, since we're hams, not laboratory technicians. But with the present trends toward VHF, at least some specialized test gear is necessary. Otherwise, the regular station equipment can't be tuned for maximum performance.

One of the simplest such items is a noise generator, for getting the VHF receiver in perfect tune. This gadget has been described many times before, so we won't repeat it again —but we do have something which transforms the usual noise-generator lashup from a so-so item to an instrument capable of laboratory accuracy.

Before going into detail, let's look at the normal method of using a noise generator: you connect the generator to the antenna input, tie the converter to the receiver, turn the avc off, connect a voltmeter to the detector load resistor in the receiver (or put an ac voltmeter across the speaker leads), and measure the voltage produced by just noise. Then you turn on the generator and adjust it for a 3 db (1.4 times the voltage) increase in output; the object is to achieve the 3 db increase with the minimum amount of current flowing in the noise generator.

However, this technique of using the noise generator is pretty sloppy, since it assumes that the receiver's detector is absolutely linear for small signals—and this assumption is almost always incorrect.

A far better technique is to hook things up just as before, except now you place three T-pads in the line between converter and receiver. The T-pads on each end of the string serve merely to clamp the line impedance at 50 ohms, but the one in the center is built for precisely 3 db loss.

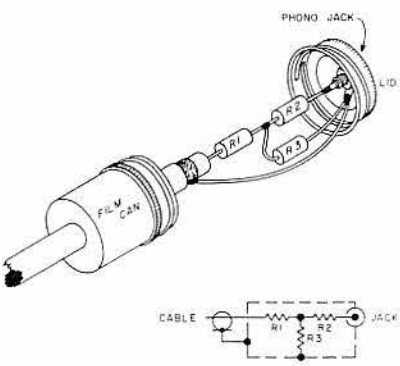
Now take the 3 db pad out and take your reading as before with the noise generator off; you don't have to turn off avc or hook up a voltmeter. The receiver's S-meter can be

used instead, since we're not measuring anything with the meter itself. It merely serves as an indicator so we can come back to the same point.

Then replace the 3 db pad in the line, turn on the generator, and crank it up until you get the same meter reading as before. Since you now have 3 db of added loss between converter and receiver you must have increased the noise power output of the converter by that same 3 db, and you could care less about the linearity of the detector!

This whole method is far from new, but previous descriptions of it have left something to be desired in the way of telling how to build the T-pad. The gadget is so simple that it must have seemed obvious to previous writers—but it does have its tricky points too.

For instance, since a T-pad consists merely of 3 resistors, it is pretty easy to just wire them up by their leads. But they are hanging in the receiver antenna lead, and present-day receivers are rather sensitive. If you happen to find a 20-meter signal, it's going to foul up your measurements!



T-Pad construction details

One of the quickest ways to sidestep this problem is to shield the pad against all outside influences—but how do you shield anything so tiny?

The answer here is to use discarded 35-mm film cans, which all photographers who shoot 35-mm cameras have in abundance. The Kodak kind seem to work best. This type has a threaded cap, with a flat spot in its center just right for drilling a ¼ inch hole to take a single-hole-mounting phono jack. At the other end, a ⅜ inch hole can be punched and lined with a rubber grommet for coax cable to enter.

Next step is to place the jack in the hole in the lid, with its solder lug on the inside (be sure to clean the paint so that a good electrical contact will result). The T-pad can be assembled as shown in the drawing with shortest possible leads, and supported by its lead connecting to the jack. Thread a short length of RG-58 through the grommetted hole, and connect its center conductor to the other lead of the pad; the shield and shunt lead of the pad connect to the solder lug of the jack.

All that's left is to wire-brush the threads on the film can for good contact, and screw the lid down tight. Presto, a shielded T-pad. A phono connector should be put on the free end of the cable.

You can make up a whole bunch of these in various loss values, and get virtually any amount of loss you want by stringing them together. And this has a whole lot more use than just using with a noise generator . . .

For instance, when you want to test an antenna, arrange for a steady signal, strong enough to register on your S-meter with the back of the antenna pointed at it. Then swing the antenna in small steps, and bring the S-meter back to the same reading by inserting additional loss between converter and receiver with the T-pads. The difference between this and S-meter indications may amaze you.

Or if you are called upon to measure the difference in signal strength between two stations, the same approach can be used. Note the S-meter reading of the weaker, then knock the stronger one back to the same reading by putting T-pads in the converter-to-receiver line. Read the db off the pads and add them up.

You can even use this in place of an S-meter if you really want to know the signal-to-noise ratio of an incoming signal with accuracy; take a reading on noise, then knock the signal back to the same point. Total up the db, and there's your answer.

Though resistance values in the pad must be precise for absolute accuracy, the pad has an inherent tolerance of small errors and you should have better than 2 percent accuracy if you use 5-percent resistors. Specifically, a 10-percent error in the resistance value of any one arm produces less than ¾ db error in the pad loss, and less than 4 percent error in impedance. Using 5-percent resistors would, of course, cut these error limits in half.

If you want to follow the approach of using a string of these pads for all purposes in the shack, it's best to make them up on a "binary" approach since this gives you the maximum number of db values with the minimum number of parts. A basic assortment might be two 1 db pads, and one each of 2 db, 4 db, 8 db, 16 db, and 32 db. Using them in series in various combinations, you can get any whole number of db from 0 to 64, which pretty well covers the range of values you may ever need. For an example, to get 50 db you would use the 32 db pad, the 16, and the 2. For 60 db, you would use the 32, the 16, the 8, and the 4.

If the ability to increase loss in 1 db steps seems a bit exotic to you in view of the fact that 3 db is only half an S-unit, then you can use a binary progression in 3 db steps; this takes one 3 db pad, one 6 db, one 12 db, and one 24 db. The range is from 0 to 45 db, 3 db at a time.

For clamping a line's impedance, it's a good idea to use at least a 3 db pad and a 6 db unit might be even better. The lower-loss pads pads may not have the ability to swamp out impedance variations on their other sides.

About all that's left to make this complete is a chart of resistance values for various loss figures. Here it is; all are for use with a 50 ohm line; to use at any other impedance, multiply these values by the ratio of the new impedance to 50 ohms:

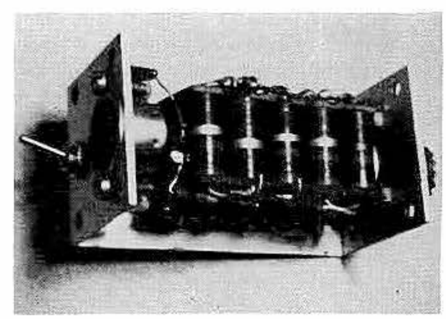
LOSS AMOUNT	R1, R2	R3
1 db	2.7	430
2 db	5.6	220
3 db	8.2	150
4 db	11	100
6 db	16	68
8 db	22	47
12 db	30	27
16 db	36	16
24 db	43	6.2
32 db	47	2.2

COMBINATION DUMMY LOAD/ ATTENUATOR NETWORK

John Schultz W2EEY

There are many instances when it is desired to use an existing transmitter as an exciter unit for a high-power linear amplifier. Many such linear amplifiers require a drive level that is only a fraction of the transmitter's output. To some degree, the transmitter can be detuned in order to reduce its output level, but this procedure is rarely possible when several orders of magnitude reduction in the power level are necessary. In such a case one can either internally modify the transmitter for a lower output level or use an alternator network between the transmitter and linear amplifier. In the latter case, the transmitter can be operated at its normal power input level and with its tuning controls at their normal settings.

The unit described in this article functions as both an *rf* attenuator and as a



A simple method of construction is employed. Based mainly on "sandwiching" the resistors used between two pieces of vectorboard. Details are given in the text. SO-239 is used as coax input connector. The circuit function switch is located below the output connector.

dummy load. The latter capability allows a transmitter to be properly tuned alone for correct operation before it is used to drive a linear amplifier. An optional wattmeter circuit is included which when calibrated allows direct reading, in watts, of the full transmitter output or of the drive level supplied to the linear amplifier.

The unit described was built for use with a nominal 100 output transmitter used primarily for SSB service. The construction used, however, can be extended to other power levels for transmitters operating on 80-10 meters. Also, using the information

Power Reduction	Resistor Factors a	b
1/4 (6db)	.3	1.3
1/5 (7db)	.4	1.1
1/10 (10db)	.5	.7
1/20 (13db)	.6	.5

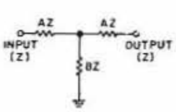


Fig. 1. Approximate resistor factors for "T" network attenuators over the ranges normally desired for exciter power output reduction.

supplied, the same type of attenuator/ dummy load can be designed for other than 50 ohm transmission line systems. The attenuator was not designed as a precision network in order to allow the use of inexpensive resistors. However, the attenuation characteristics are quite satisfactory for the intended usage.

Besides its application as a power reducer when driving a linear amplifier, the unit can be used with a transmitter whenever a quick, known level of power output reduction is needed for operating purposes, approximate gain measurements, etc.

Circuit

Fig. 1 shows the circuit values for a generalized T network attenuator that can be used in any impedance unbalanced transmission line. The scaling factors are only shown for those power reduction levels most likely to be needed when driving a linear amplifier with a 75-200 watt transmitter, in order to avoid unnecessary detail. Factors for intermediate power reduction values can be found by interpolation to a satisfactory degree or one can consult an electronics handbook. The basis of the attenuator/ dummy load network is to find the combination of resistor arms that will provide the desired attenuation and still be able to be connected together to form a dummy load of the correct value. Fig. 2 shows one possible combination. Each resistor bank has a value of about 20 ohms (5 resistors of 100 ohms each in parallel). In one position of the DPDT switch, the resistor banks are formed into a "T" network attenuator. In the other

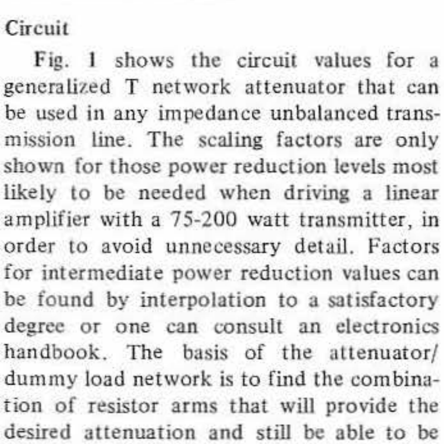


Fig. 2. Circuit of one possible dummy load/attenuator network providing about 10 db power reduction. Optional wattmeter circuit is also included.

switch position, all three banks are placed in series as a dummy load connected across the input only. The resistance values which result are not exactly those shown in Fig. 1 for a 10db alternator. However, they are close enough to be effective and some tailoring of the individual legs is possible since each of the resistor bank values vary by a few ohms due to the tolerance of the resistors used. An optional voltmeter circuit is also shown in **Fig. 2** connected to one pole of the DPDT switch. It can be used as a relative power output indicator or if calibrated, as described later, actually measure the power output of the transmitter and of the attenuator.

Many variations of the basic idea are possible. **Fig. 3** shows the use of four banks of 100 ohm resistors. All four are used to form an attenuator that comes reasonably close to the values required for 7db attenuation in a 50 ohm system. Only three are used in series for the dummy load function. In this case only a simple SPST switch is necessary to disconnect the output. The same *rf* voltmeter circuit as used in **Fig. 2** may be added if desired. The switch, in fact, could be eliminated entirely if one were willing to disconnect the output termination in order to use the dummy load feature.

Whatever combination of resistance banks are used in order to achieve a desired attenuation value and the correct dummy load resistance, care must be taken that each resistance bank has sufficient power dissipation capability. The dissipation in each leg of the "T" network varies according to the attenuation level and can be calculated by Ohms Law. In general, a continuous power rating for a resistor bank equal to about

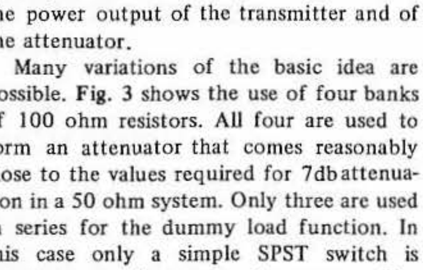


Fig. 3. Another dummy load/attenuator configuration possible with the 100 ohm resistor banks. It provides about a 1/5 power reduction (7db) when used as an attenuator.

one-third of the SSB peak power rating seems to suffice, including for quick tune-up on CW. For keyed CW service, the power rating should be increased to at least one-half the key-down power level.

Construction

The approach of using a relatively large number of 2 watt composition resistors is far less expensive than using specific value *rf* non-inductive resistors of 10-30 watts power rating. In quantities of more than 10, IRC type RC-2, 2 watt, 10% tolerance resistors

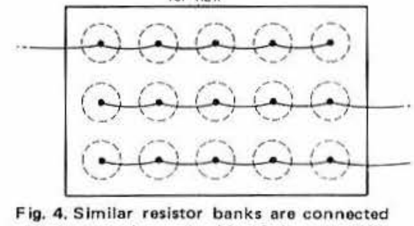


Fig. 4. Similar resistor banks are connected together on the underside of the assembly.

cost about 9 cents each. So, one can achieve a 40 watt unit for less than $2 resistor cost. Banks composed of these resistors work well up to 30 mc as long as the interconnecting leads are kept short.

The photograph shows the construction used by the author for the circuit of **Fig. 2.** Similar construction can be used for larger size units as well. As shown in the photograph, the 15 resistors in rows of 5 each are sandwiched between two 1-1/8" x 1-7/8" pieces of vectorboard. None of the resistors physically touches. The wiring is done using the resistor leads. This construction is somewhat compact to expect full, continuous power dissipation from the unit but suffices for intermittent use. The frame measures 2¾" x 1½" x 1½". A cover is not absolutely necessary since the minor radiation that takes place is not important in this application. If a cover is used, it certainly should be of a perforated type to allow maximum air flow. A SD-239 connector is used at one end of the frame for the input. A dual connector is used at the other end, but normally one would use two RCA type phono jacks–one for the output and one for a meter circuit. The switch is located immediately below the output connector–a miniature Alco MST type.

Calibration

If it is desired to calibrate the voltmeter circuit as a wattmeter, it is necessary to use a probe and VTVM. Using the unit as a dummy load, the *rf* voltage is measured at the input and the power calculated. The 50K ohm potentiometer is used to set the meter at full scale for the highest power level used. The *rf* voltage is measured and the power level calculated in order to calibrate the meter for lesser power levels leaving the potentiometer at its "set" value. The same procedure is followed to calibrate the meter for the output power level by measuring the output *rf* voltage when the unit is used as a "T" attenuator and connected to a regular dummy load. The calibration should be made on the lowest frequency band used and rechecked on the highest frequency band used. If the readings differ significantly on the highest frequency band from those established, it may be necessary to add a few mmf capacitance across the diode in the voltmeter circuit in order to compensate for the slightest reactance present in the circuit.

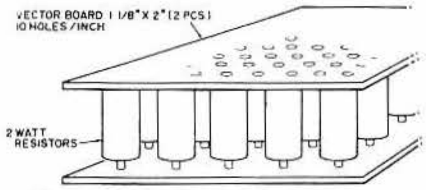


Fig. 5. Sketch showing details of resistor "sandwich" assembly.

Operation

When used between a transmitter and the 50 ohm input of a linear amplifier, the unit is first used as a dummy load for tune-up of the transmitter. The unit is then switched (with the transmitter unkeyed) to its attenuator position. In most cases, no returning of the transmitter should be necessary unless the input of the linear amplifier is particularly reactive.

Summary

The unit described is not intended as a precision attenuator or power measuring device. However, it will perform very well for its intended applications and costs far less than more sophisticated units performing the same functions.

THE MINICAN

Sam Kelly W6JTT

The Heathkit "Cantenna" has proven to be a major breakthrough in the field of dummy loads for ham use. Unfortunately, it isn't the most convenient thing to use on a small work bench with low power rigs! Borrowing their idea, I built this load for use with transmitters in the 5 to 15 watt range. The parts are few: a Campbell soup tin can, four one watt resistors, a UG-254-A connector, a short piece of 5/16 inch brass tubing and transformer oil.

Fig. 1 is a sketch of the assembled unit. The 50 ohm resistance was made up of three 15 ohm and one 5 ohm one watt carbon resistors.

First sand a can lid from a larger size can until it is free of paint. Drill a ½ inch hole through the center of the lid, and a ¼ inch hole on the perimiter. Mount the coaxial connector through the center hole. Solder a 1 inch length of 5/16 in. brass tubing over the ¼ inch hole. Solder the resistors as shown. Center the lid on the can and solder the lid to the can. Use a file to remove all rough edges. Mask the connector with masking tape and paint the can to prevent rusting.

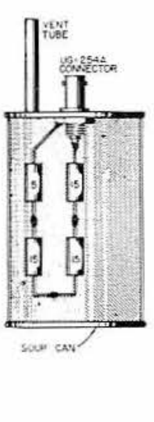
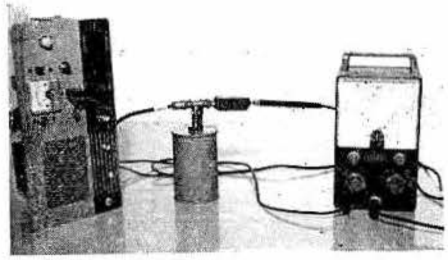


Fig. 1. Construction of the Minican. Main parts are a soup can, coax connector and resistors.


The Minican in use with the companion detector.

Fill the can with transformer oil. A good grade of automatic transmission fluid was used in one load with no degredation in performance. However, it probably is not advisable as the fluid has a relatively low ignition temperature and might create a fire hazard.

The load was tested by running it for five hours with an input of 15 watts of 50 MHz rf. The can became warm, but the resistors showed no signs of overheating.

A maximum VSWR of 1.5:1 was obtained at 234 MHz. The measurement was made at this frequency because an automatic test set was available.

A companion rf detector unit shown in **Fig. 2** was built in a two inch section of ¾ inch square extruded brass stock. A Dage 394-1 BNC connector is mounted on one end for connecting to the RF circuit, while the DC output to the VTVM is a tip jack.

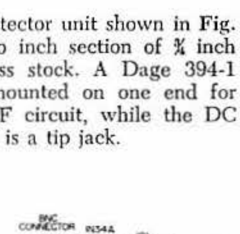


Fig. 2. Rf detector for use with the Minicon.

THE TINY TERMINATOR

Jim Kyle K5JKX

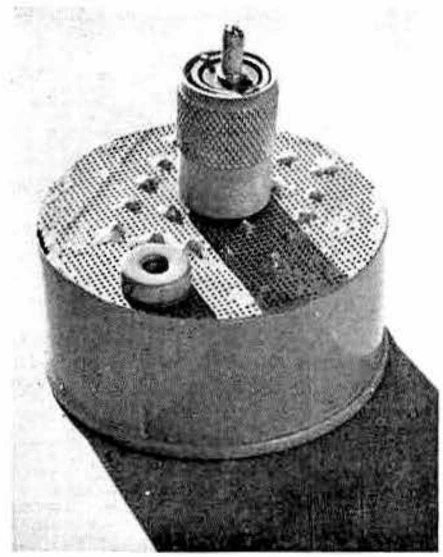
HAVE you ever felt the need for a dummy load which would also indicate accurately the actual rf output power of a transmitter?

You can buy such a beastie, you know. The Bird *Termaline*, standard of the two-way communication industry, shouldn't set you back much more than a C-note . . .

But you can also build one at considerable less outlay, and that's what this article is all about.

As the photographs show, there's almost nothing to the "Tiny Terminator"—nothing, that is, but a 50-ohm load for any transmitter, which will absorb 20 watts for days on end and will handle 40 watts for brief periods (a minor modification can double these ratings), will *not* radiate rf into the ether after the fashion of the "standard" light bulb load, will allow accurate measurement of output power up past 225 mc, and can be built in less than two hours for less than $5.

You can see by the schematic that there's nothing to the device electrically; the tricks are all mechanical. Electrically, the Tiny Terminator consists of 20 (that's what we said)

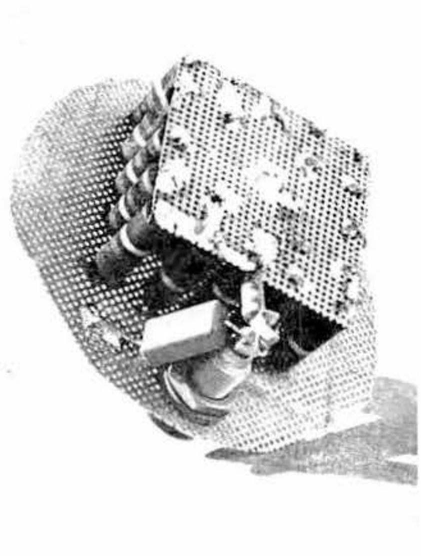


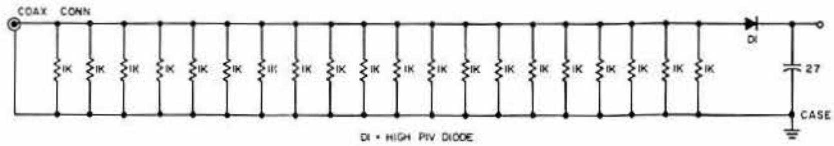
1000-ohm 1-watt resistors connected in parallel, with a crystal diode running from the hot end of the composite resistor to the meter jack and a 27 mmfd capacitor bypassing the meter.

Mechanically, the big problem with a unit such as this is the problem of keeping the load resistive regardless of frequency. Resistor leads have inductance (about 25 millimicrohenries per inch) so we get rid of the leads as completely as possible. This is done by punching holes in a flat plate, passing the lead through the hole until the resistor is flush with the plate, and soldering rapidly with a hot iron (an Ungar 47-watt 1100-degree tip was used in building the model shown) so that the resistor body won't cook before the leads and plate are joined.

The flat plate has capacitance. This is avoided by keeping the plate shielded from outside influences, and separated as far as possible from its shield.

The shield, incidentally, is the bottom of 1½ inches of a Canada Dry cola, soldered all around the edge to the front resistor plate. This confines all rf inside the terminator.





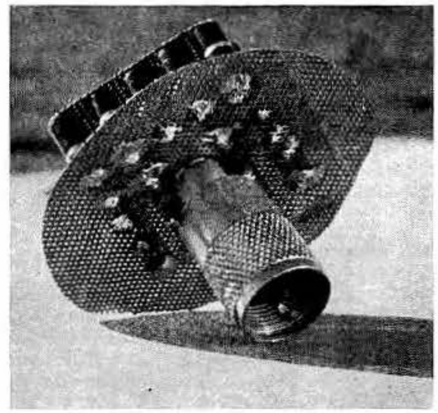
D1 = HIGH PIV DIODE

Addition of the crystal diode (a 1N34 was used, but a higher-voltage unit is recommended if you ever expect to measure power higher than 8 watts) and the bypass capacitor provide the power-measuring feature. These two components, in conjunction with an external voltmeter of at least 1000 ohms per volt sensitivity, provide you a peak-reading ac voltmeter. The voltage indicated on the meter will be equal to the peak value of rf voltage present across the load. Squaring the voltage and dividing by 50 (the resistance) will give you the *peak* power. Most power ratings are in rms values rather than peak; multiplying the indicated voltage by 0.707 before squaring will give you the rms power output.

The unit shown in the photos used perforated brass stock for the resistor plates; this happened only because a length of the brass was on hand in the junkbox at the time. A cut-out tin can lid will work equally well and will be much less expensive.

Not visible in the photos is the means of connecting the hot end of the resistor plate. A hole was punched in the middle of the hot plate and a length of No. 14 bare wire was soldered in, then filed off flush on the rear side. The bare wire was threaded through the coax connector and soldered to the center contact after checking for possible shorts.

The coax connector itself is held in place by a solder joint all around the rim of the cable-end aperture (see photo). This joint, if well made, provides plenty of strength.



Earlier, we mentioned that a minor modification would double the power rating. That modification is this: instead of 1-watt resistors, use the 2-watt variety. If you really want to go high-power, use 50 2700-ohm 2-watt resistors and have a terminator which will absorb 100 watts continuously and 200 watts ICAS. However, one that big will cost more—and you'll probably have to use a coffee can for the shield instead of the cola can used here.